PRELIMINARY REPORT

External Ecosystem Task Team Report to NOAA Science Advisory Board: Evolving an Ecosystem Approach to Science and Management Throughout NOAA and its Partners

By

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Preface

Both the public media and scientific circles are demanding better management of our ocean and aquatic environments. As a society, we value the benefits of clean water and coasts as well as in sustainably managed marine and coastal resources. Many critics argue that these benefits are declining as a result of inadequate single sector management and lack of coordination throughout the coastal ocean and the Great Lakes. Some argue that a broader management framework informed by ecosystem science and research would improve management and restore or increase benefits. Legislative proposals are being made at local, state, regional and national levels to reorient management mandates and institutions to accommodate this broader societal initiative. Others argue that it is not necessary to shift to a different management paradigm and that properly implemented Best Management Practices will restore declining social benefits. Further, they argue that society has neither the political will nor the resources necessary to implement a broader ecosystem-based approach to management. These debates and supporting trend data are prompting NOAA to build from its strong marine science base towards a future where social benefits from our uses of aquatic ecosystems are secure and sustainable. As part of those efforts to get ahead of the debate, the NOAA Science Advisory Board appointed the eight members of the External Ecosystem Task Team [eETT] to provide outside perspectives on how NOAA could further refine and direct its approach in the near term and over the next few decades.

The eETT is pleased to provide this Preliminary Report of its findings and recommendations for consideration by the Science Advisory Board. Placing the Report for review by the public, scientific community, tribes, environmental groups, user groups and various local, state and federal agency personnel, should engender discussion on how to employ ecosystem science to improve management decisions and how to evolve institutions capable of managing at different ecosystem scales. We fundamentally agree that the most direct way for NOAA to grow into an agency that manages human activities in a full ecosystem context is to start by expanding the use of ecosystem science and research under present mandates. In doing so, it should emphasize the development of ecosystem science integrating resources across the agency, and encourage organizational form to evolve with function over the longer term. Although the eETT provides the rationale for this incremental and adaptive approach to developing and using scientific information and research in NOAA we seek comment and advice on how to improve this approach as finalize this report in mid-2006.

Above all we want to make clear that although we have taken a critical look at NOAA's ecosystem science and research enterprise our purpose is not to criticize the people and programs at work in NOAA today. Rather, we want to encourage the expansion of efforts made so far to move a very large agency serving multiple and sometimes conflicting mandates toward an ecosystem approach to management. We offer our recommendations to promote NOAA's ability to fulfill its ecosystem vision and we ask that user groups and environmental stakeholders join in this effort.

David Fluharty, Chair

Executive Summary and Key Recommendations

NOAA, the National Oceanic and Atmospheric Administration, is the nation's premier ocean research and management agency. It derives its mandates from over 90 acts of Congress, spanning missions from fisheries and protected species management, response to natural disasters and oil spills, management of marine sanctuaries and reserves, responsibilities to document and understand ocean-related phenomena supporting the US economy, and other requirements. NOAA's "wet" or oceanic side is dominated by its ecosystem science enterprise, with activities included in four of its Line Offices: the National Marine Fisheries (NMFS), National Ocean Service (NOS), Office of Oceanic and Atmospheric Research (OAR), and the National Environmental Satellite, Data, and Information Service (NESDIS). Additionally, the Office of Marine and Aircraft Operations (OMAO) operates a fleet of research vessels and aircraft supporting the Ecosystem Goal. Currently NOAA spends about $1.5 billion annually in support of its ecosystem programs (including ship and aircraft time). Science supporting NOAA's management activities spans the gamut from applied monitoring programs to process-based research to understand fundamental properties of the oceans affecting its resources.

In 2004 NOAA issued an independent review of NOAA's "dry" and "wet" research programs examining their alignment and relevance to its service responsibilities. Among its findings,

> *"The Review Team recommendation for better using the functional and/or regional location and co-location of NOAA laboratories, possibly using a regional center model, will also help improve the connections between line office efforts. In this vein, we recommend that NOAA should establish an external Task Team to evaluate the structure and function of ecosystem research in the NMFS, NOS, and OAR laboratories, with an eye for further rationalization."*

Based on this recommendation, NOAA's Science Advisory Board (SAB) established in mid-2005 the External Ecosystem Task Team (eETT) with specific terms of reference to answer two important questions regarding ecosystem sciences:

Is the mix of scientific activities conducted and/or sponsored by NOAA appropriate for its mission needs, including its legislative and regulatory requirements, in terms of:

- Subject matter,
- Distribution along the continuum from long term research to products for immediate use (including mandated scientific advice),
- Internal and external (to NOAA) balance?
- Links to international science programs?, in addition:

How should NOAA organize its ecosystem research and science enterprise, in terms of:

- The relationship to non-ecosystem science activities (e.g., weather, climate or mapping), which is in part an artificial separation,
- The continuum from long term research to information products for immediate use (including mandated scientific advice),

- Line Office distribution,
- Program Structure used in NOAA's Planning, Programming, Budgeting, and Execution System,
- Other categorization schemes, such as by scientific discipline, mission area or mandate (implicitly including all sectors that are users of science advice), ecosystem or region, internal/external, etc.?

This document provides detailed findings of the eETT regarding the mix of science activities NOAA is conducting or should conduct, as well as recommendations regarding the organization of its science activities. The eETT reviewed the various science programs of NOAA and its line office and "matrix structures" used to provide program oversight and coordination. Additionally, we interviewed Congressional staff, the White House Office of Management and Budget, high-level officials of other federal agencies, and NOAA's senior management team for science to understand the context for its research and to explore various alternative models for organizing NOAA's ecosystem science.

Examination of an agency's science portfolio needs to begin with an analysis of its missions – both current and especially in the future. Early in its work the eETT was briefed by line office representatives on current legislative and internal mission drivers. NOAA's future science needs are highlighted in its 5-year research and its 20-year vision documents. The 20-year vision provides a series of long-term science themes detailing emerging issues of human use in the marine and coastal realms. To supplement the 20-year vision, we asked NOAA to provide a series of "white papers" outlining the science that would be needed in 2020 to support of decision making in six topic areas: Ecosystem Responses to Climate Variability, Management of Living Marine Resources in an Ecosystem Context, Freshwater Issues, Marine Zoning and Coastal Zone Management, Ecological Forecasting, and Science Requirements to Identify and Balance Societal Objectives. Taken together with NOAA's 5- and 20-year plans they emphasize the importance of making NOAA's ecosystem science products more integrative and comprehensive, to address complex problems of marine and coastal resource management. These complexities arise from competing uses for scarce resources and a widening array of human activities affecting our coasts. None of NOAA's major science programs has sufficient resources to fully meet the demands for information and advisory services. However, NOAA requires more than increased resources to meet demands for comprehensive ecosystem science services. More integration among NOAA's science products is essential, and can only arise if the various line offices and programs work together on integrated ecosystem monitoring and research and advisory products. The core of this report examines the range of mechanisms NOAA might consider in meeting the need for comprehensive ecosystem science products that serve multiple mission drivers.

Since the Research Review Report, NOAA's matrix management mechanisms have strengthened and matured. The Planning, Programming, Budgeting and Execution system (PPBES) and NOAA's internal boards and committees have become more important as institutions for coordinating among the four mission goals (e.g., Ecosystems, Weather and Water, Climate, and Commerce and Transportation). NOAA's Ocean Council (NOS), and the Research Council now provide routine advice and oversight of activities that span two or more line offices. However, although these matrix institutions provide planning oversight, these activities are primarily seen as high-level or headquarters functions, particularly by scientists in NOAA's field offices (of which there are over 340). In order to provide integrated ecosystem products and services there is a need to integrate planning and program delivery at regional scales as well.

One of the principal tenets of NOAA's definition of an ecosystem approach to management is inherently geographically based, making a regional focus for integration of ecosystem science essential. NOAA has defined eight large marine ecosystems (LMEs) as an initial basis for providing ecosystem-based science. Although the geographic scale relevant to particular ecosystem phenomena is frequently smaller than LMEs, and occasionally at broader (ocean basin or global) scales, the regional ecosystems are a pragmatic basis for integrating ecosystem science. Within these areas NOAA line offices currently provide a wide range of traditional science and management activities including fishery and protected species population assessments, marine area management, coastal zone and fisheries management, as well as a variety of monitoring and research activities aimed at understanding linkages between ecosystem components. Nonetheless, problems arise when one considers how NOAA can provide coordinated and consistent science products that incorporate relevant research and monitoring results form diverse regional centers. Not all NOAA line offices have a regional structure that aligns well with these eight (or any other) defined LMEs. For example, whereas NMFS maintains six regional science centers, OAR has three "wet-side" laboratories [(Pacific Marine Environmental Laboratory (PMEL), Atlantic Oceanographic and Meteorological Laboratory (AOML), and Great Lakes Environmental Research Laboratory (GLERL)], and a number of cooperative institutes. NOS established a number of Coastal Science Centers and they are concentrated in the southeastern US. NESDIS has a small number of service centers for the country. A critical question for this review was then, how best can NOAA organize itself to provide integrated ecosystem science activities at the LME level?

The eETT focused its attention on three basic options for providing regionally focused and integrated ecosystem science. An option would be for NOAA to re-organize its line office components in a scheme that would align various activities regionally around a common ecosystem theme. This would presumably entail re-aligning existing laboratories and activities such as monitoring in sanctuaries and reserves and other similar local activities. Problems with this wholesale re-organization are many-fold. First, as noted above, NOAA does not currently have physical laboratories nor many other core activities replicated in all Regions. Realignment would mean, for example, that the Alaskan ecosystems would be well-served by NMFS and OAR, but less so by NOS and NESDIS. Second, if existing LO programs were re-aligned in this scheme; NOAA might lose the national focus important for many of its activities, such as consistency in the application of national standards for living resource management. Third, the existing LO structure and programs in many cases are the result of direct Congressional authorization. Moving major programs or establishing new line offices may be time-consuming and politically difficult. Finally, the transition costs to productivity and of physical moves of people and facilities would result in short term (e.g., 5 year) reductions in productivity, not to mention the operational monetary costs of such re-alignment which may be daunting.

A second alternative is to examine selected programs for potential moves among the line offices to achieve better integration of similar programs and attendant efficiencies. Our report identifies several specific programs that we believe should be considered for further evaluation, including programs for monitoring and abating toxic contamination, physical oceanography capabilities, modeling and related activities, and others. The eETT stopped short of recommending specific moves because of the many intricacies that must be considered in such moves. Given the scope of the current study and the make up of the panel, the eETT recommends that the identified programs be assessed for potential re-alignment under the oversight of the SAB.

The third option for enhancing regional cooperation in the delivery of ecosystem science products is the establishment of cross-line office teams focusing on each of the identified LMEs. These regional teams would act as regional analogs to the EGT, with specific missions to provide guidance, identify priorities and integrate science across participating NOAA LOs. NOAA maintains extensive facilities and/or Cooperative Institutes fronting each of the LMEs (except the Caribbean) in NMFS, NOS and OAR, The eETT recommends the establishment of these Regional Ecosystem Science Coordination Groups as pragmatic way forward that encourages collaboration across NOAA and its science partners to produce specific products (detailed below), and to act as NOAA's link to other agencies and associations working in the LMEs.

Given the focus on research coordination across NOAA at the LME level we further recommend that one of the primary duties of these regional groups be the production of integrated ecosystem assessments (IEAs). Periodic assessment of the status of ecosystems across a wide variety of biological and physical attributes would allow for a coordinated evaluation of the status of the national marine and coastal ecosystems, and the sustainability of human uses of those ecosystems. Furthermore IEAs would have currency with a wide variety of stakeholders and agencies that rely on science support (e.g., fisheries management, Coastal Zone Management, Sanctuaries, etc.). IEAs can also be the forum for integration of information collected by NOAA with other regional entities including other federal agencies, states and academic institutions at multiple scales. A critical function of the regional ecosystem groups will be to archive and mobilize ecosystem data sets in ways that enhance collaboration and synthesis within and among the LMEs.

The eETT also considered models of separating NOAA's science from its management responsibilities and separating its long-term high risk research from shorter-term science. However, neither of these models offers significant benefits over the current organizational structures, and both have risks. Separating science from management introduces the risk of mission drift. Imposing an arbitrary schism along the continuum of research to application, risks a loss of focus in long-term research. Also, ecosystem research produces a constant stream of useful information that must be picked up for specific applications, regardless of the ultimate time frame of the research program as a whole.

Overall the panel found that NOAA's ecosystem enterprise current has important gaps and inconsistencies in the science products and services produced to meet its diverse missions. **None of its mission areas are fully resourced, and maximum efficiencies are not being achieved due to overlap in products and services from different LOs serving different mission areas. All mission areas identified significant gaps to realizing their strategic visions.** Acknowledging the overall inadequate resources, the eETT identified a few high priority areas in which targeted new investments seem especially warranted. NOAA needs to consider how to strengthen analytical capacities in the form of new tools for modeling and forecasting, social science methods for linking ecosystem science to governance and for identifying how humans respond to changing ecosystem components, methods for assessing and defining optimal ecosystem structure and function, ecosystem roles of toxics and contaminants, biodiversity and taxonomy to support an ecosystem approach, data archiving and integration and ecosystem impacts of human activities.

Overall the eETT found NOAA's ecosystem enterprise to be vibrant, responsive to client needs, and populated by highly motivated, well respected scientists, working at or near the forefront of their disciplines. Transitioning from NOAA's orientation of serving many single sectoral mandates to provision of integrated "multiple-use" ecosystem science products must be sensitive to both the scientists and the client needs. Moves that NOAA makes to integrate its delivery of ecosystem products should not diminish the productivity of its scientists, and the new products must maintain the responsiveness of NOAA science to users of its products**. The transition is a process that can take place more or less rapidly to the extent that the direction, pace, and process of change is supported by consistent leadership, agency personnel, and the external environment. Even in countries where legislative mandates have provided authoritative policy frameworks for developing ecosystem approaches, the road to implementation is slow. This reflects the need to link top down direction and allocation of resources with bottom up processes that engage stakeholders in the enterprise.**

A comprehensive review of such a large and complex agency is daunting under any circumstance. When that agency is already acting to implement an ecosystem approach to its science and management the assignment grows even more challenging as the target is continually changing. Further, the geographic scope of NOAA's responsibilities gives it involvement in science and research at multiple scales, e.g., watersheds, nearshore, offshore and global. Finally, the review is performed by an external group each of whom has full-time responsibilities, constraining the level of detail that can be realistically accomplished. The eETT has had to adopt a high level of generality in its assessment and recommendations while at the same time trying to provide clear direction. Its recommendations offer pragmatic alternatives to help steer the ship in the direction it is already tending (albeit slowly, and with limited navigational aids). The eETT anticipates that by building on outsiders' perspectives on agency processes, NOAA can act through its existing EGT to perform the detailed assessments of specific programs that are potential candidates for re-alignment, and oversee the development of integrative mechanisms that will enhance its products. As with the RRT report earlier, that the NOAA SAB in conjunction with the NEC can review progress after two years to apply the advice regarding the pace and rate of transition to a full ecosystem approach. A key element to encourage innovative thinking is the recommendation that NOAA create a competitive grant process that encourages cross Line Office proposals to address important ecosystem assessment issues.

PART I INTRODUCTION

This report provides advice on how to improve NOAA's ecosystem science enterprise over the next two decades. We have sought to provide direction on practical pathways for NOAA to take in concert with existing legislative mandates and with an uncertain fiscal and management environment. We have used NOAA's definition of "ecosystem" throughout the report, agreeing that the breadth of topics covered by the definition is appropriate for a review of ecosystem science in NOAA.

> *For NOAA's purposes, an ecosystem is defined as a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics* (Appendix 2).

When we refer to the "ecosystem science enterprise" we include all aspects of planning, conduct, and application of ecosystem science – development of hypotheses, monitoring, modeling and analysis, field and experimental research, development and provision of advice, and communication of results to all audiences. There is no question that the American public is supportive of improved management of its marine and coastal ecosystems and that existing approaches are at best only partially meeting those expectations. Therefore, we anticipate public feedback to assist us in making recommendations.

The eETT divided its task into five steps, represented in the organization of this report. First, we reviewed the complex statement of task and determined what methods could be used with available time and resources to accomplish the task. Second we examined the current context for NOAA's science and management responsibilities. The context includes what other nations are doing to implement ecosystem approaches, as well as how their science enterprises are organized to accomplish this task. In addition, we tried to assess future trends in demands for ecosystem approaches. Third, we developed some guiding considerations for organizing our view of ecosystem science and its multiple roles in providing information and support to policy management, and in increasing understanding of planet Earth and how society relates to marine environments and resources. Based on these considerations and our review of on-going NOAA activities and relationships with other agencies and partners, we developed findings and recommendations in 12 broad categories. These findings and recommendations are in the fourth section of the report. Part five of the report returns to the statement of task. We integrate our findings and recommendations to answer the major questions posed to the eETT.

I A Statement of Task

The origin of the External[1] Ecosystem Task Team (eETT) is in the recommendation of the NOAA Research Review Team (http://www.sab.noaa.gov/Reports/Reports.html) that NOAA should establish an external review team to evaluate and strengthen the structure and function of ecosystem research in NOAA. This recommendation was further elaborated in an extensive statement of task by NOAA (Appendix 2). In broadest terms NOAA poses two questions:

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[1] This is in contrast to the Internal Ecosystem Task Team set up within NOAA to work on implementation of the Ecosystem Goal approach adopted by NOAA [website reference].

1. Is the mix of scientific activities conducted and/or sponsored by NOAA appropriate for its ecosystem science needs, including its legislative and regulatory requirements, in terms of subject matter, distribution along the continuum from long term research to products for immediate use (including mandated scientific advice) and between internal and external to NOAA, and links to international science programs? Is the mix optimal, and if not, how can it be improved?

2. How should NOAA organize its ecosystem research and science enterprise, in terms of, the relationship to non-ecosystem science activities (e.g., weather, climate or mapping), the continuum from long term research to information products for immediate use (including mandated scientific advice), Line Office distribution, Program Structure used in NOAA's Planning, Programming, Budgeting, and Execution System, other categorization schemes such as by scientific discipline mission area or mandate (implicitly including all sectors that are users of science advice) ecosystem or region, internal vs. external, etc. Is the organization optimal, and if not, can it be improved?

I B Approach and Methods

A task team of eight members was selected by the NOAA Science Advisory Board (SAB) in consultation with NOAA leadership from a list of persons nominated via Federal Register Notice. The organizational meeting of the eETT took place in Washington, DC, June 20-22, 2005 in conjunction with a meeting of SAB. Informational briefings were provided by all the Line Offices [http://eett.intranets.com]. A work plan was developed by the eETT to gain a representative sample of perspectives from NOAA's Line Offices and regions.

An important aspect of this review is to position NOAA to meet a series of emerging issues that will become more prominent over the next two decades. The US Ocean Commission and the Pew Commission reflect a global trend in management of human activities in the sea in their centerpiece recommendations for greater use of ecosystem approaches to management. Moreover the projected increase in human habitation at the coasts will drive more user conflicts for scarce resources, and will intensify activities that will make the attainment of all NOAA's legislated mandates increasingly difficult. Consequently the integrated management of the coastal zone and marine ecosystems more generally will become more essential and prominent. The NOAA 5-year and 20-year plans were reviewed for insight into NOAA's vision of how ecosystem science will develop to support this trend to ecosystem approaches to more integrated management. In addition, the eETT and iETT requested six ecosystem white papers (Appendix 3) to explore some of the escalating challenges that society faces and how NOAA will address them as we approach the year 2020:

- Management of Living Marine Resources in an Ecosystem Context
- Ecosystem Responses to Climate Variability
- Freshwater Issues
- Marine Zoning and Coastal Zone Management
- Near-Real Time Ecological Forecasting
- Science Requirements to Identify and Balance Societal Objectives

Over the summer and fall of 2005 eETT members interviewed numerous NOAA staff, Ecosystem Goal Team Leads and program managers, senior leadership, and other NOAA decision makers. A wide variety of external stakeholders (e.g., other agencies, Ocean Studies Board (OSB) members, Congressional staff, Office of Management and Budget (OMB), US Commission on Ocean Policy (USCOP) members were interviewed. In addition eETT members attended conferences, agency meetings, and talked with user groups. We discussed the degree to which common criteria for research location can apply with the Physical and Social Science Task Team (PSTT). Our primary goal was to inventory NOAA's ecosystem portfolio geographically and organizationally, and to gain of sense of the clients which each unit felt it served with what ecosystem products. In addition, we held bi-weekly or weekly conference calls involving the eETT, iETT, and NOAA leadership to gain information, plan, or discuss issues.

The mix of ecosystem science activities in which NOAA should be investing is obviously guided by its mandates, and should be informed by and cognizant of international developments in marine ecosystem science and management and international commitments that NOAA must meet. Equally, it should be guided by considerations of how marine and coastal resources and ecosystems are influenced directly or indirectly by human activities. Discussing the material gained through the consultation in the context of these considerations led the eETT to three principles that guided its assessment of NOAA's portfolio of ecosystem-related activities (Section III).: Based on this work we met October 26-27, 2005 in Seattle to develop the outline of our Report and to detail preliminary recommendations. These were vetted to the NOAA SAB during its November 9, 2005 meeting. Discussion with the members of the SAB provided further guidance around which this report was written. The eETT began drafting its report during December 11-13, 2005 and followed up with an intensive drafting meeting January 11-13, 2006 Seattle followed by considerable electronic traffic of ever growing file dimensions until the end of February 2006. The Preliminary Report text was accepted by the eETT in late February in order to garner public comment for further deliberations.

PART II THE CONTEXT OF NOAA'S ECOSYSTEM SCIENCE AND RESEARCH

NOAA's ecosystem science "portfolio" consists of a broad set of monitoring, research, and advisory services that it has implemented in order to meet its statutory mandated missions for aquatic resource and coastal management. This portfolio developed over time as a result of an expanding set of Congressional mandates, dating back originally to 1871 and the establishment of the U.S. Fish Commission (the progenitor of the National Marine Fisheries Service). These mandates set the foundation for NOAA's various statutory missions to meet societal objectives for fisheries management, protected species recovery, coastal zone management, managing estuarine and coastal sanctuaries and reserves, and for scientific research and services in pursuit of defined goals. Changes to NOAA's ecosystem science enterprise must ensure that this plethora of Congressional mandates to NOAA and other agencies with ocean or natural resources responsibilities continue to be met, and with great efficiency.

Additionally, NOAA participates in a number of international management and scientific organizations as a result of legislation, treaties, and conventions. These activities require NOAA to maintain a global focus for many of its key research activities. Moreover, the demand for an increased focus on ecosystem science is seen in agencies with comparable mandates to NOAA in many other countries. This review took note of how the challenges of delivering ecosystem science are confronted internationally, as a possible source of insights into novel solutions to major challenges.

The various requirements and drivers of NOAA's research influence the way in which the Agency has structured its activities, for example, the division of its responsibilities into line offices (LOs). More recently, NOAA has adopted a matrix organizational structure in order to help address issues that cut across line office boundaries, with management and research in an ecosystem context as one of the featured cross-cutting programs. A major focus of this review is to assess the effectiveness of the line office structure and the newer matrix elements as they relate to the provision of science supporting understanding and managing in an ecosystem context. To do so, we first establish a baseline of NOAA's current ecosystem related activities and emerging activities.

II A The International Context

Throughout the world, science and assessments supporting management of human activities in marine ecosystems are showing similar trends toward an ecosystem approach. In Europe, the North Sea Council of Ministers adopted the Bergen Declaration in 2002, committing all the European Countries to take an ecosystem approach to management of human activities in the North Sea and calling on the scientific community to develop operational ecosystem management objectives as a guide. The revised Common Fisheries Policy in 2004 featured the ecosystem approach and acknowledged as a priority the need to consider ecosystem impacts of fishing. That was followed quickly by the European Commission developing a Discussion Paper on a European Marine Strategy, which has led to the European Marine Policy scheduled for a general vote in 2006.

The European Marine Strategy has an ecosystem approach as its central theme, and the Guidelines for Implementation are built on ecosystem assessments, integrated management, and regional delivery of programs. In parallel, the Sixth and Seventh Frameworks have increasingly emphasized research support for marine ecosystem science. The International Council for Exploration of the Sea (ICES), as the main source of science advice to the various management and policy agencies in the European Seas, has also responded not just by establishing a third Advisory Committee on Ecosystems and giving ecosystem issues prominence in advice from the Advisory Committee on Fisheries Management and the Advisory Committee on the Marine Environment, but also by establishing new Working Groups for conducting integrated assessments at both descriptive and analytical scales (http://www.ices.dk/products/icesadvice.asp).

In Australia, the Sustainability Act requires that all industries impacting environmental quality meet a high level of accountability for ecological sustainability. The fisheries management agencies are required to include ecosystem audits of the sustainability in their management plans, and seek science advice in a broad ecosystem context. Integrated management of human activities in the coastal zone is also a legislated priority, and the governance, management and science advisory processes are all adapting to work in an integrated ecosystem management context. CSIRO, the main government science body, has responded to these changes with both program refocusing and organisational change. In July 2005, the Marine and Atmosphere units of CSIRO were merged to better link research in ocean and atmosphere. In the amalgamated CSIRO unit, all marine science is organized in thematic units (Marine Environment Prediction, Climate Process and Prediction, Sustainable Aquaculture Production, Sustainable Fisheries, and Managing Multiple Uses) which emphasise an ecosystem approach to all science in support of management and policy, and an integrated approach to planning and decision-making.

In Canada, the Preamble to the Oceans Act (1997) features an ecosystem approach, precautionary approach, and integrated management as the cornerstones for policy and program development under the Oceans Act. Canada has identified several Large Ocean Management Areas, which are the subject of Integrated Ecosystem Assessments as the foundation for suites of operational ecosystem management objectives. Two such assessments have been completed and three more will be completed by the end of 2006. Canada's commitment to an ecosystem approach in fisheries was embodied in the text of the St John's Declaration (May 2005) and is being written into the revisions to the Fisheries Act. Science support for the management and policy sectors of the Department of Fisheries and Oceans (DFO) is also being revised as part of Science Renewal, and the DFO Science Management Board has identified ecosystem science as the single greatest priority in the reallocations of science resources under Science Renewal.

The commitment to an ecosystem focus is not restricted to the developed world. The FAO Code of Conduct for Responsible Fishing adopted Annex 4 in 2004, placing the FAO support for fisheries in developing and developed states onto an ecosystem-based footing. This reflects the widespread support among UN states for the Reykjavik Declaration (2002) that stressed the need to have the management of the world's fisheries apply an ecosystem approach. Likewise, the support for fair but effective processes for ecocertification of international fisheries gives sustainability of fisheries in an ecosystem context equal weight with sustainable harvesting of the target species.

II B Legal Context for NOAA's Science Activities

Table II.A.1 presents a partial list of US Federal legislation authorizing NOAA to undertake science programs in the coastal oceans and the freshwater ecosystems of the Great Lakes.. Each line office participating in NOAA's ecosystem science programs has primary responsibility to implement some of these legislative mandates. In some cases these are assigned to individual Line Offices, otherwise they may require representation by NOAA or by the Secretary of Commerce. Many of these acts require formal reports to Congress on their implementation, and most have been periodically reauthorized to clarify science and management provisions. Some of these acts and treaties authorize specific sums of money supporting them, however, in many cases appropriations have either not been commensurate with the scope of science required to meet these mandates, or have not kept pace with inflation.

NOAA's authorizing legislation is only one set of mission drivers to which the Agency responds. For example, building on the US Ocean Commission and Pew Ocean Commission reports, the President's US Ocean Action plan detailed nearly 200 specific recommendations for which NOAA had exclusive or shared responsibility (http://ocean.ceq.gov/actionplan.pdf). The Ocean Action plan created a number of interagency coordinating committees, including the National

Science and Technology Council's Joint Subcommittee on Oceans Science and Technology (JSOST). The JSOST reports to the NSTC Committee on Science and the Committee on Environment and Natural Resources in addition to the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI). One of the duties of the JSOST is to prepare a comprehensive Ocean Research Priorities Plan, which is currently under development, with significant input from NOAA. NOAA has executive branch responsibilities to provide science input to a number of management and coordinating groups formed as a result of the establishment of the Committee on Ocean Policy (http://ocean.ceq.gov/). Additional executive branch mandates require NOAA to coordinate its science activities with other federal agencies, states, tribes and other countries.

In addition to legal and executive-level mandates, the judicial branch of government is often involved in scientific issues driving some of NOAA's science requirements. Because NOAA is also a regulatory agency, there is ongoing litigation, sometimes involving the scientific basis supporting its management decisions. Accordingly, some of its science programs stem from legal findings or legislative action in response to them. Because of the potential for litigation, NOAA has developed rigorous peer review processes for science supporting many of its management activities (particularly in fisheries), and to be compliant with provisions of the federal Information Quality Act (http://www.whitehouse.gov/omb/inforeg/agency_info_quality_links.html).

Table II.A.1. A partial listing of legislative requirements mandating NOAA's Ecosystem Science Programs

º Magnuson-Stevens Fishery Conservation and Management Act (1976, 1996)
º Marine Mammal Protection Act
º Endangered Species Act
º National Marine Sanctuary Act
º Coastal Zone Management Act of 1972, Coastal Zone Act Amendments of 1990
º Coral Reef Conservation Act of 2000
º Clean Water Act
º National Environmental Policy Act
º Harmful Algal Bloom and Hypoxia Research and Control Act of 1998
º Comprehensive Environmental Response, Compensation, and Liability Act
º Energy Policy Act of 2005
º Information Quality Act
º Estuary Restoration Act of 2000 (ERA):
º National Sea Grant College Program Act
º Oceans and Human Health Act
º National Aquaculture Act of 1980
º Ocean Dumping Act (Title II of the Marine Protection, Research, and Sanctuaries Act)
º National Coastal Monitoring Act
º Water Resources Development Act of 1992
º Coastal Wetlands Planning, Protection, and Restoration Act
º Pollution Prevention and Control Act
º Federal Power Act
º Fish and Wildlife Coordination Act
º Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990
º Whaling Convention Act
º Coastal Ocean Program, § 201(c) of Public Law 102-567
º Government Performance and Results Act
º Global Change Research Act
º National Materials and Minerals Policy Research and Development Act
º Oil Pollution Act
º Atlantic Coastal Fishery Cooperative Management Act
º Northern Pacific Halibut Act
º Atlantic Tunas Convention / International Convention for the Conservation of Atlantic Tunas
º Interjurisdictional Fisheries Act of 1986 / Anadromous Fish Conservation Act 1965 (AFCA)
º High Seas Fishing Compliance Act
º Tuna Conventions Act of 1950 Agreement on the International Dolphin Conservation Program
º Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)
º PICES Treaty (North Pacific Marine Science Organization), ratified December 6, 1991
º ICES Treaty
º NAFO Treaty
º USA-Canada Whiting Treaty
º North Atlantic salmon Conservation Organization Treaty
º International Whaling Commission Treaty
º Convention on Conservation and Management of Pollock Resources in the Central Bering Sea
º Pacific Salmon Treaty Act of 1985
º National Oceanic and Atmospheric Administration Authorization Act of 1992

II C NOAA Today -- NOAA's Ecosystem-related Activities

As the nation's principal ocean agency, NOAA undertakes science and management programs related to living marine resources (fisheries and protected species), coastal zone management, including marine sanctuaries and estuarine research reserves, and coral reefs, and related activities, consistent with its mandates (Table II.C.1). The Agency is comprised of seven "line offices" (Figure II.C.1, http://www.pco.noaa.gov/org/NOAA_Organization.htm) , supported by additional headquarters corporate services including financial, information technology, congressional affairs, public affairs, education and allied functions. Its ecosystem research, observing, and management activities are distributed over four NOAA line offices (Figure II.C.2), each conducting a varying amount of ecosystem-related research, depending on its mandates and program needs: the National Marine Fisheries Service (58% of the ecosystem budget in 2005), the National Ocean Service (30% of the ecosystem budget), Oceanic and Atmospheric Research (11%), and the National Environmental Satellite, Data and Information Service (1%). Additionally, under its Office of Marine and Aircraft Operations (OMAO), NOAA operates a fleet of research vessels and aircraft supporting ecosystem missions. NOAA's ecosystem "portfolio" in FY 2005 included investments of about $1.3 billion, which was about 1/3 of NOAA's overall budget (Table II.C.1, Figure II.C.1). Activities undertaken by each of the line offices are described in detail in the materials provided in Appendix A, and at: http://www.noaa.gov/.

The ecosystem science portfolio undertaken by NOAA is primarily developed by the individual line offices (LOs) to address responsibilities under their assigned missions, with the Ecosystem Goal Team (EGT) intended to provide coordination across LOs. In order to coordinate research and observational systems, NOAA has developed a number of boards, councils and teams (http://www.ppi.noaa.gov/councils.htm). NOAA's Research Council is the primary entity facilitating inter-line office policies concerning science. The Research Council is responsible for developing NOAA's 5-year research plan (http://nrc.noaa.gov/Docs/NOAA_5-Year_Research_Plan_010605.pdf). The 5-year research plan describes current activities, facilities and missions, and provides an institutional context for meeting current challenges faced by the line offices and the Agency. In contrast, the 20-year research vision of the agency (http://nrc.noaa.gov/Docs/Final_20-Year_Research_Vision.pdf) describes how NOAA may position itself to meet future environmental challenges. NOAA's long-term vision for science is:

> *"An informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions"*

In its 20-year vision, NOAA has outlined a series of long-term societal challenges, and seeks to position its research activities to help meet them.

In addition to the Research Council, various aspects of NOAA's science and observing system are coordinated through internal boards and councils including the NOAA Observing System Council, the NOAA Ocean Council, the Transition Board (dealing with transition of systems from research to operations), and the Platform Allocation Council (allocating NOAA ship and aircraft time to individual projects). Additionally, NOAA seeks external input to NOAA's science program, through the Science Advisory Board (http://www.sab.noaa.gov/). Overseeing these boards is the NOAA Executive Committee (NEC) which is chaired by the Undersecretary for Oceans and Atmosphere, and includes all of NOAA's top tier leadership.

PPBES Process

NOAA has established a matrix organizational structure around four organizing themes that describe the bulk of its mission mandates (Figure II.C.2). This matrix organization explicitly recognizes that many of the demands made of the agency involve resources controlled by two or more of its line offices. Specifically, four cross-line office mission goals have been established to:

- Ecosystems: Ensure the sustainable use of resources and balance competing uses of coastal and marine ecosystems, recognizing both their human and natural components. Line Offices contributing are: NMFS, NOS, NESDIS, and OAR
- Climate: Understand changes in climate, including the El Niño phenomenon, to ensure that we can plan and respond properly. Line Offices contributing are: OAR, NESDIS, NWS, and NMFS.
- Weather and Water: Provide data and forecasts for weather and water cycle events, including storms, droughts and floods. Line Offices contributing are: NWS, OAR, NOS and NESDIS.
- Commerce and Transportation: Provide weather, climate, and ecosystem information to make sure individual and commercial transportation is safe, efficient and environmentally sound. Line Offices Contributing are: NOS, NWS, and NESDIS.

Additionally, a Mission Support goal manages ship, satellite, and aircraft time, and facilities.

The mission goal teams have primary responsibility in NOAA's Planning, Programming, Budgeting, and Execution System (PPBES) Figure II.C.3. This is a comprehensive planning and budgeting system that seeks to align NOAA's strategic goals with its long-term budget needs. Because of the complexity of the federal government budget cycle, the PPBES process is, at any one time, working on three NOAA budgets: the current fiscal year (e.g., reporting on the "execution" of its current budget), the following year (e.g., FY+1), and two years hence. Although complex, this cycle has been developed to explicitly recognize NOAA's growing cross-line office approaches to its mandates, achieve synergies and economies of scale, and reduce potential organizational redundancies and duplications of effort. The PPBES process occurs continuously throughout the year.

Ecosystem Goal Team (EGT)

NOAA's Ecosystem Goal Team (http://ecosystems.noaa.gov/general_information.htm) was created to integrate its ecosystem science, research, and management activities among the four participating line offices. This integration is the key to leveraging science investments and developing initiatives to understand and predict the totality of interactions between human and the other components of marine and coastal ecosystems. The EGT consists of nine programs

(Table II.C.1), some of which include activities within one LO, others (the “matrix programs”) include multiple LO representation. Those programs designated “matrixed” include habitat, corals, aquaculture, enforcement, ecosystem observations and ecosystem research. The programs are led by senior scientific staff familiar with each of the program activities, with official representatives in each program assigned from each participating line office. The programs develop comprehensive lists of their capabilities (the areas of science and management for which they are responsible), as well as performance metrics to describe their progress in meeting annual and long-term goals (Table II.C.1). In addition to the line offices, the programs are responsible for annual execution of the budget, including assuring that milestones are met and that grants, contracts and other financial and personnel requirements are met. The program teams also develop budgets necessary to meet their “current” program needs, as well as their “100%” program needs. The focus of the goal team planning is for a five year period, beginning with the time frame of FY+3 (for example, the current plan being developed under the PPBES process is the FY-09-13).

NOAA’s Ecosystem Resources

Currently, NOAA has about 7,000 employees supporting EGT activities, with the vast majority assigned it its 340 field centers, offices and laboratories (Figures II.C.3-9). The current (FY-05) budget for ecosystem-related activities is about $1.3 billion, with the largest programs being ecosystem observations, ecosystem research, coastal zone programs, and protected resources science and management (Table II.C.1). In addition to ecosystem activities undertaken in its science and research facilities, NOAA supports a comprehensive network of cooperative and joint institutes, many of which are described in Table II.C.2. These institutes, along with the National Undersea Research Program (NURP) Centers, Sea Grant institutions, and other cooperative arrangements, allow NOAA to leverage its assets and to engage academic partners in pursuit of ecosystem research, and technology in support of its diverse mandates. Some of these institutes maintain regional focus, whereas others pursue issues of national or global scope.

In order to fully meet its ecosystem mandates, NOAA needs substantially core funding in all its programs. The majority of the difference lies in funding for habitat mapping and recovery, ecosystem observations, and ecosystem research activities.

Table II.C.1. Programs contained in NOAA's Ecosystem Goal Team with their capabilities, associated line offices and their approximate FY05 budgets.

Ecosystem Goal Team Program	Capabilities	NOAA Line Offices	Budget FY-05 ($m)
Habitat	- Protect habitat - Restore habitat - Assess, characterize - Stewardship	NMFS, NOS, OAR	$88.5
Corals	- Observe and assess - Predict, warn, and respond - Research reef decline - Manage threats - Strengthen partnerships	NOS, NESDIS, NMFS, OAR	$28.7
Coastal & Marine	- Ecosystem approaches to management - Education and outreach - Science, technology and observations - Regional ecosystem integration	NOS	$264.1
Protected Species	- Pre-listing conservation - Status, listing - Recovery, conservation - Outreach, education - International coordination, cooperation	NMFS	$176.4
Fisheries Management	- Regulatory analysis, evaluation, implementation - Fishery plan development - State Partnerships - Policy development, implementation - International coordination, cooperation - Economic sustainability - Outreach and education	NMFS	$143.5

Aquaculture	- Legal, regulatory, administrative - Science, technology - Education, outreach	NMFS, NOS, OAR, NESDIS	$6.7
Enforcement	- Investigations - Patrol, inspections - Outreach, education - Management, training, support	NMFS, NOS	$44.0
Ecosystem Observations	- Fishery monitor, assess, forecast - Protected resources monitor, assess - Ecosystem monitor, assess, forecast - Economic, sociocultural monitor, assess - Data management, technology transfer - Education, outreach	NMFS, NESDIS, OAR, NOS	$339.9
Ecosystem Research	- Characterize ecosystem health - Causes, consequences of ecosystem change - Predict ecological impacts - Technology, tools - Outreach, education	OAR, NOS, NMFS	$269.4
EGT Total			$1,361.2
NOAA Total			$4,945.9

Table II.C.2. NOAA's Cooperative and Joint Institutes for scientific research supporting line offices involved in the ecosystem mission goal.

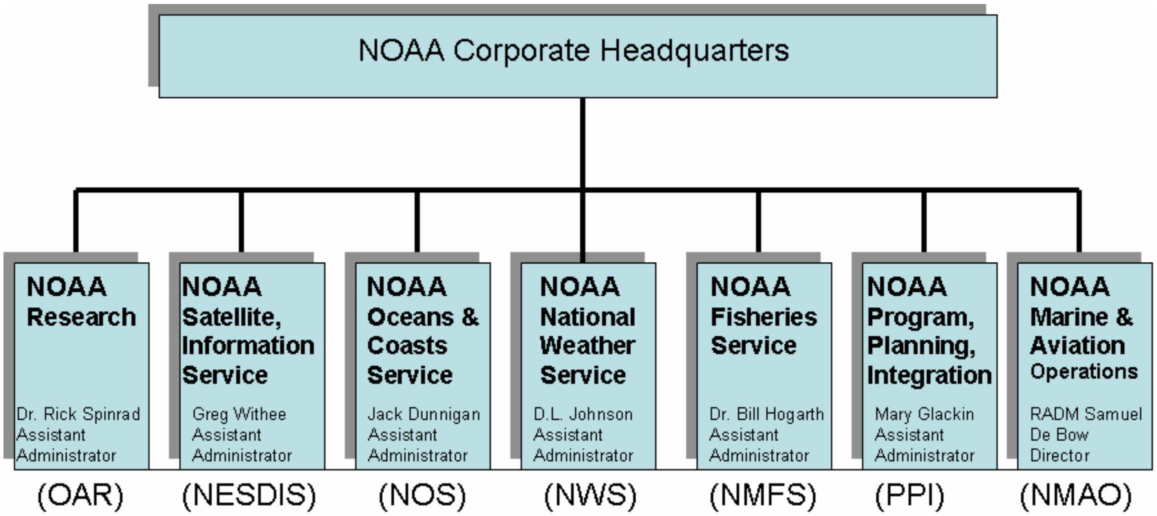
Institute – Sponsoring Line Office	Location	Primary Missions
Cooperative Institute for Arctic Research (CIFAR) - OAR	Fairbanks, Alaska	Fisheries oceanography, hydrography, sea ice, atmospheric research, climate dynamics, environmental prediction
Cooperative Institute for Atmospheric and Terrestrial Applications (CIASTA) - OAR	Las Vegas/Reno, Nevada	Weather research, climate, air quality, terrestrial ecosystems, hydrology
Cooperative Institute for Climate Applications and Research (CICAR) - OAR	Palisades, New York	Climate variability, climate change prediction and assessment
Cooperative Institute for Climate and Ocean Research (CICOR) - OAR	Woods Hole, Massachusetts	Coastal ocean and nearshore processes, ocean influences on climate, marine ecosystem process analysis
Cooperative Institute for Climate Science (CICS) - OAR	Princeton, New Jersey	Earth systems studies, biogeochemistry, coastal processes, paleoclimate
Cooperative Institute for Limnology and Ecosystems Research (CILER) - OAR	Ann Arbor, Michigan	Climate and large-lake dynamics, coastal and near-shore processes, remote sensing, marine engineering
Cooperative Institute for Marine and Atmospheric Studies (CIMAS) - OAR	Miami, Florida	Climate variability, fisheries dynamics, coastal ocean processes
Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) - OAR	Norman, Oklahoma	Forecast improvements, climatic effects, socioeconomic effects of weather systems, regional climate studies
Cooperative Institute for Research in the Atmosphere (CIRA) - OAR	Fort Collins, Colorado	Global and mesoscale weather and climate research, cloud physics, satellite observations, air quality, numerical modeling
Cooperative Institute for Research in Environmental Sciences (CIRES) - OAR	Boulder, Colorado	Environmental chemistry, biology, atmospheric and climate dynamics, polar processes, solar-terrestrial environment
Joint Institute for Marine and Atmospheric Research (JIMAR) - OAR	Honolulu, Hawaii	Equatorial oceanography, climate research, tsunamis, fisheries oceanography, coastal research
Joint Institute for Marine Observations (JIMO) -	La Jolla, California	Coupled ocean-atmosphere research, biological oceanography,

OAR		marine geology and geophysics, ocean technology
Joint Institute for the Study of the Atmosphere and Ocean (JISAO) - OAR	Seattle, Washington	Climate variability, environmental chemistry, estuarine processes, fisheries recruitment
Cooperative Institute for Marine Resources Studies (CIMRS) - NMFS	Newport, Oregon	Living and non-living marine resources and their interrelationships
Cooperative Marine Education and Research Program (CMER) - NMFS	Amherst, Massachusetts, Kingston, Rhode Island, New Brunswick, New Jersey, Gloucester Point, Hampton, Virginia	Resource management and marine environmental studies supporting NOAA and NMFS missions
Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) - NOS	Durham, New Hampshire	Develop and apply new environmental technologies and techniques
Joint Hydrographic Center (JHC) - NESDIS	Durham, New Hampshire	Ocean mapping, hydrographic science, and applications
Cooperative Institute for Climate Studies (CICS) - NESDIS	College Park, Maryland	Satellite climatology, climate diagnostics, modeling, prediction
Cooperative Institute for Meteorological Satellite Studies (CIMSS) - NESDIS	Madison, Wisconsin	Passive remote sensing for meteorological and surface-based applications
Cooperative Institute for Oceanographic Satellite Studies (CIOSS) - NESDIS	Corvallis, Oregon	Ocean remote sensing and ocean-atmosphere modeling

A vital element of ecosystem approaches is their geographic definition. NOAA has organized its activities through the EGT to include 8 regional ecosystems adjacent to the USA coasts (Figures II.C.1-9). These regional ecosystems provide one basis for organizing scientific and management activities, recognizing the alignment between physical oceanographic processes, biodiversity, and human use activities. Although this geographic alignment is not the sole one appropriate for all ecosystem activities (often one needs to define ecosystems at smaller spatial scales, and sometimes at larger ones), the regional ecosystem boundaries are useful and appropriate as a way to organize research supporting multiple management requirements. When

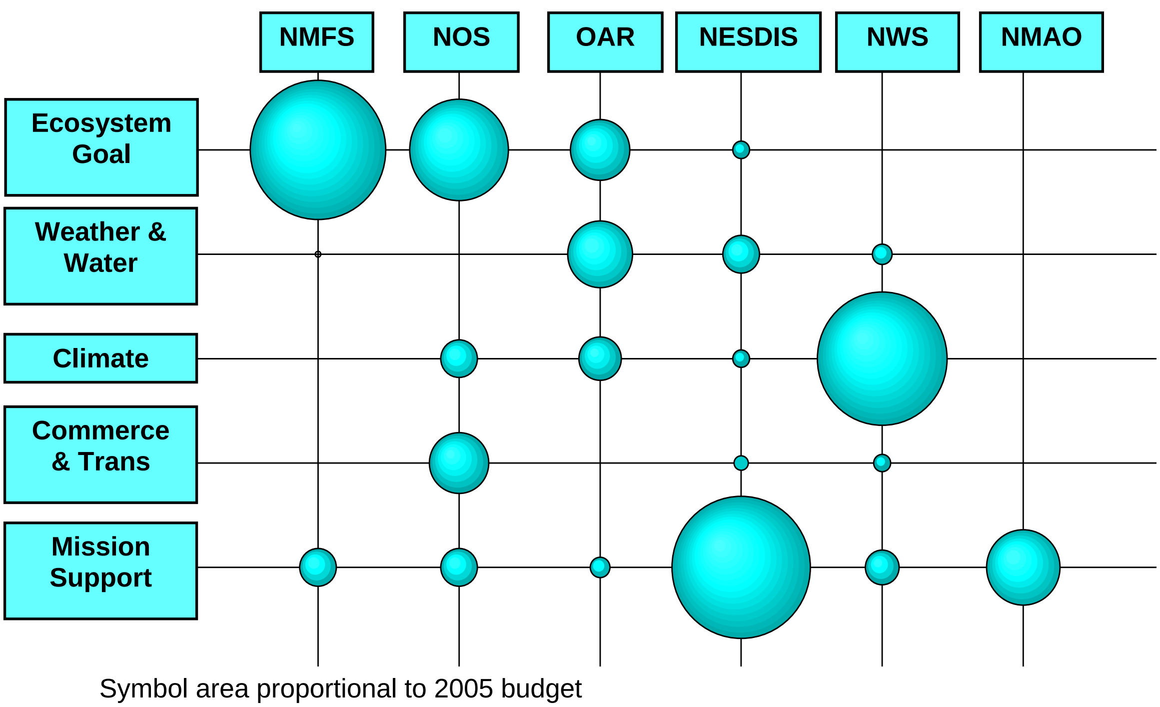
NOAA's centers, laboratories and cooperative institutes are aligned with the regional ecosystem boundaries, it is apparent that all line offices supporting the EGT have a physical presence adjacent to nearly all of the 8 regional marine ecosystems (the exception being the Caribbean Sea). The importance of the physical alignment of NOAA's facilities with the regional ecosystems is discussed later in our report.

Figure II.C.1. NOAA's line office structure supporting ecosystem, climate, weather and water, and commerce and transportation, and mission support activities



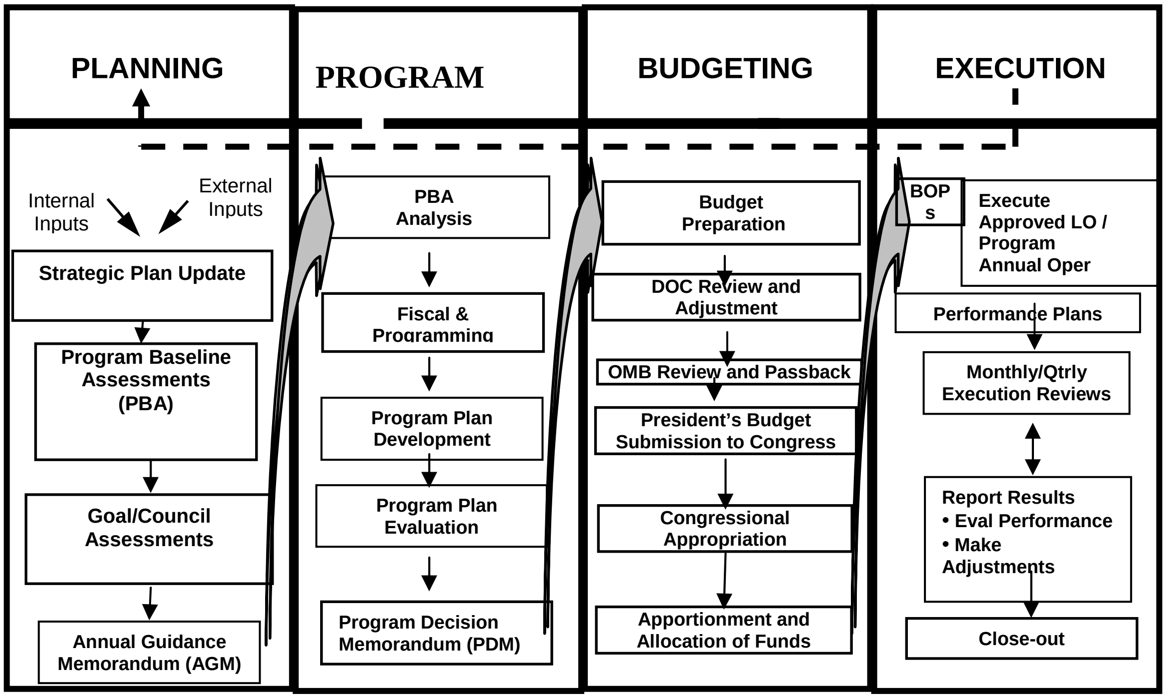
Source: Mike Ford, NOAA

Figure II.C.2. NOAA's matrix structure integrating line offices and goal teams



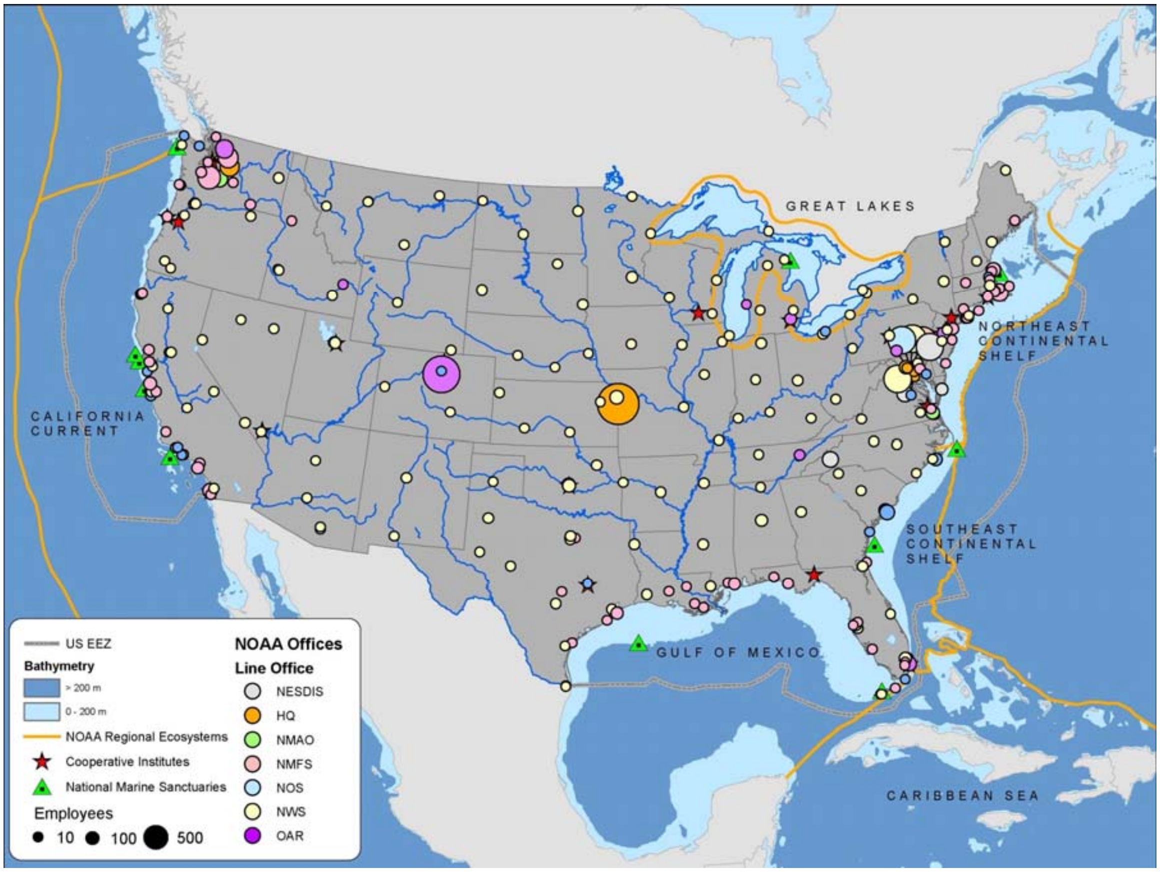
Source: Mike Ford, NOAA

Figure II.C.3. Phases of NOAA's PPBES process – annual cycle



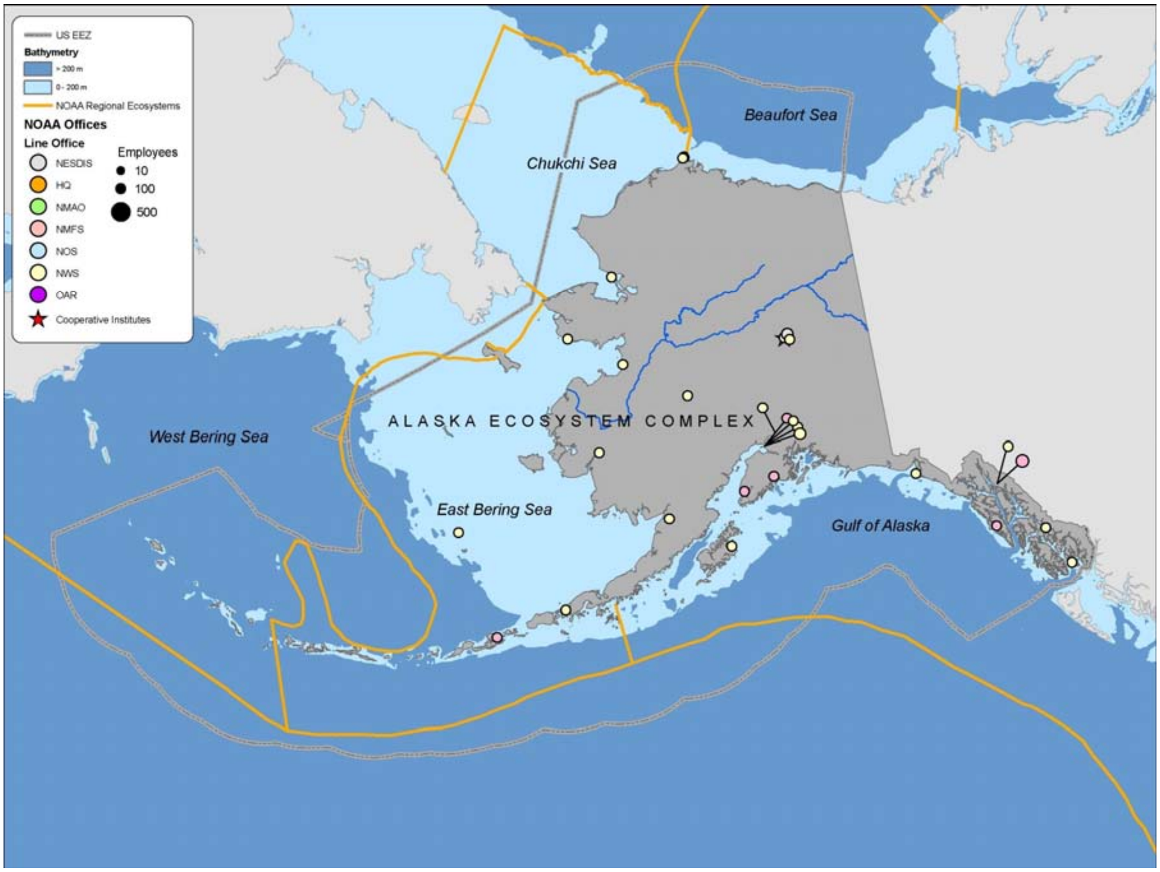
Source: Mike Ford, NOAA

Figure II.C.4 Location of NOAA offices in the continental USA, by line office



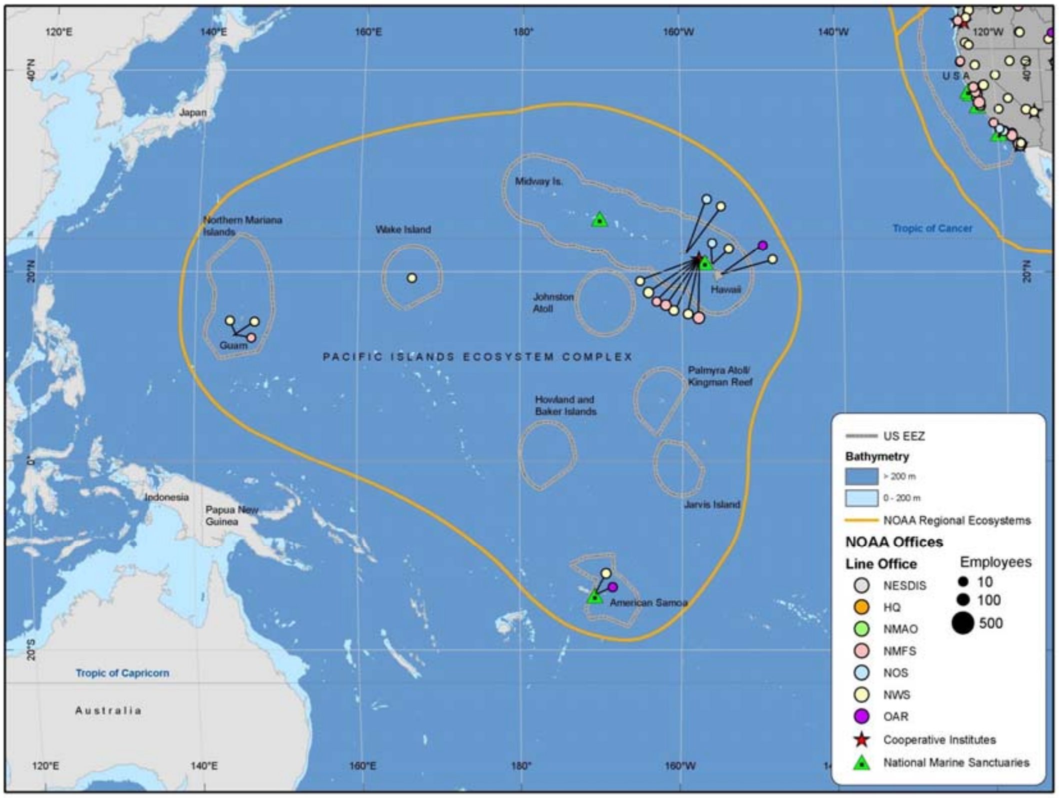
Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. NFA refers to NOAA Financial and Administrative Centers. Boundaries of the large marine ecosystems are given (yellow line)

Figure II.C.5. Location of NOAA offices in Alaska, by line office



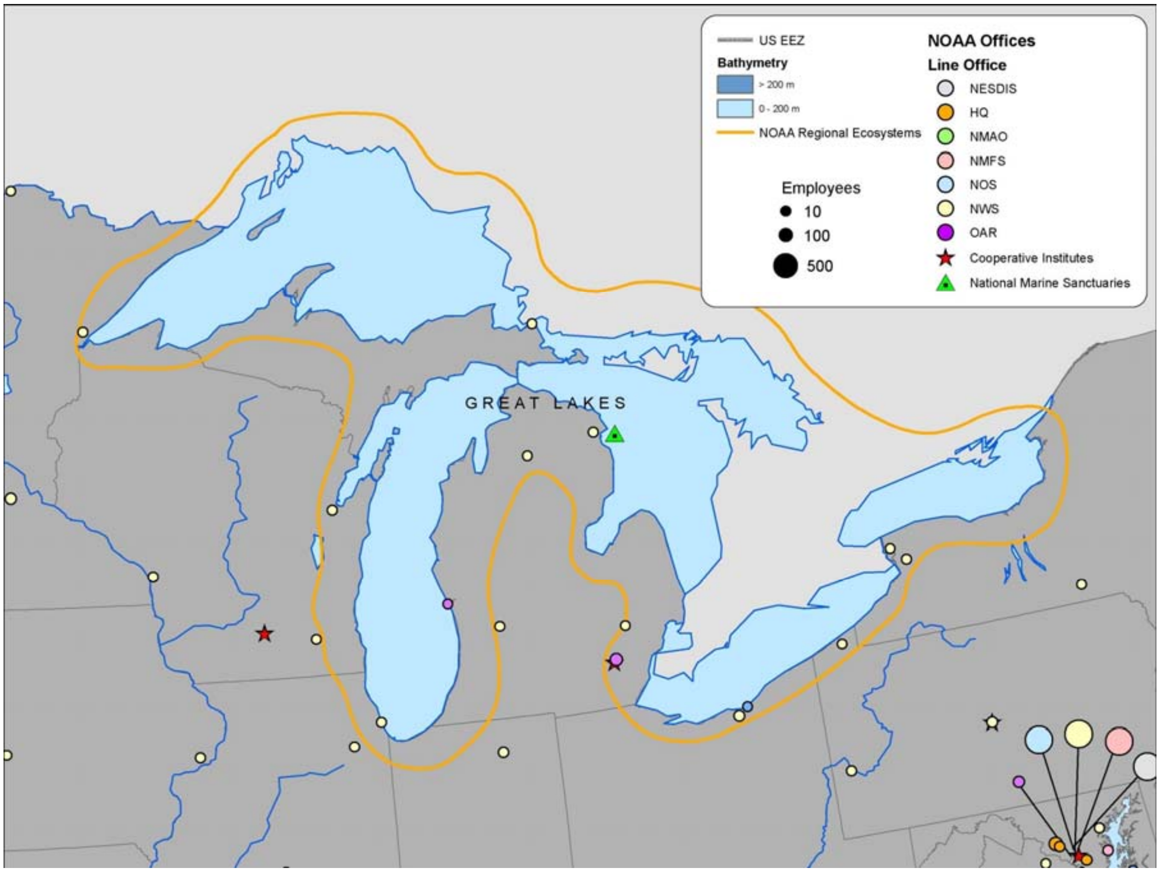
Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. Boundaries of the large marine ecosystems are given (yellow line).

Figure II.C.6. Location of NOAA offices in the Pacific Islands, by line office



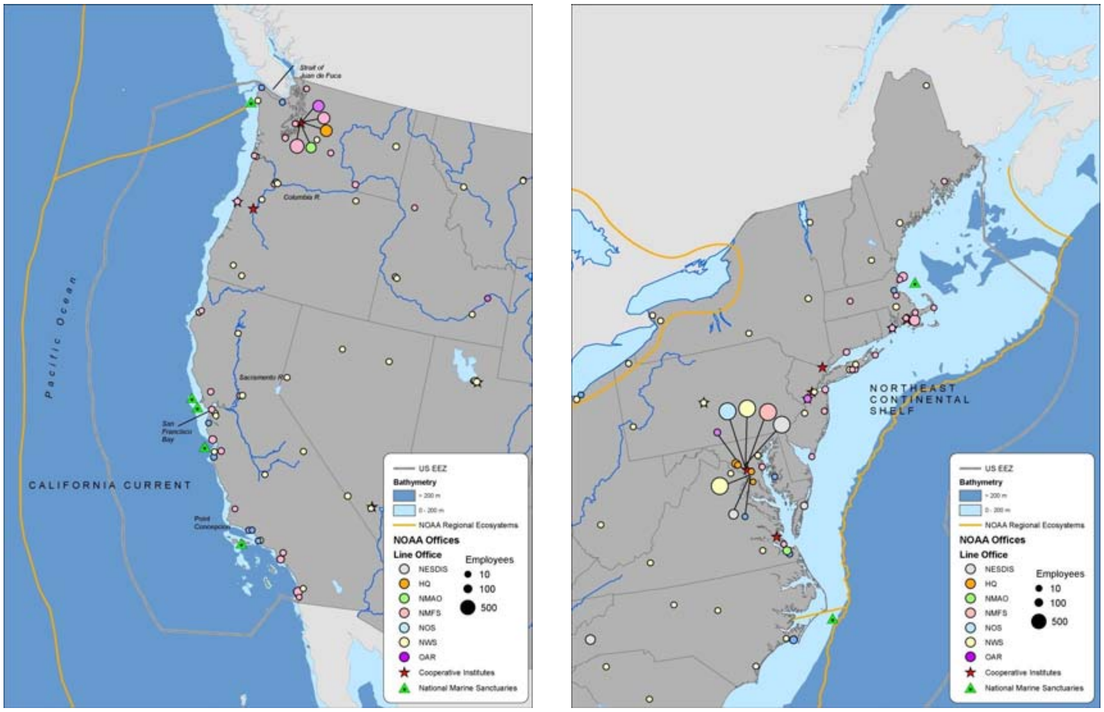
Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. Boundaries of the large marine ecosystems are given (yellow line).

Figure II.C.7 Location of NOAA offices in the Great Lakes, by line office



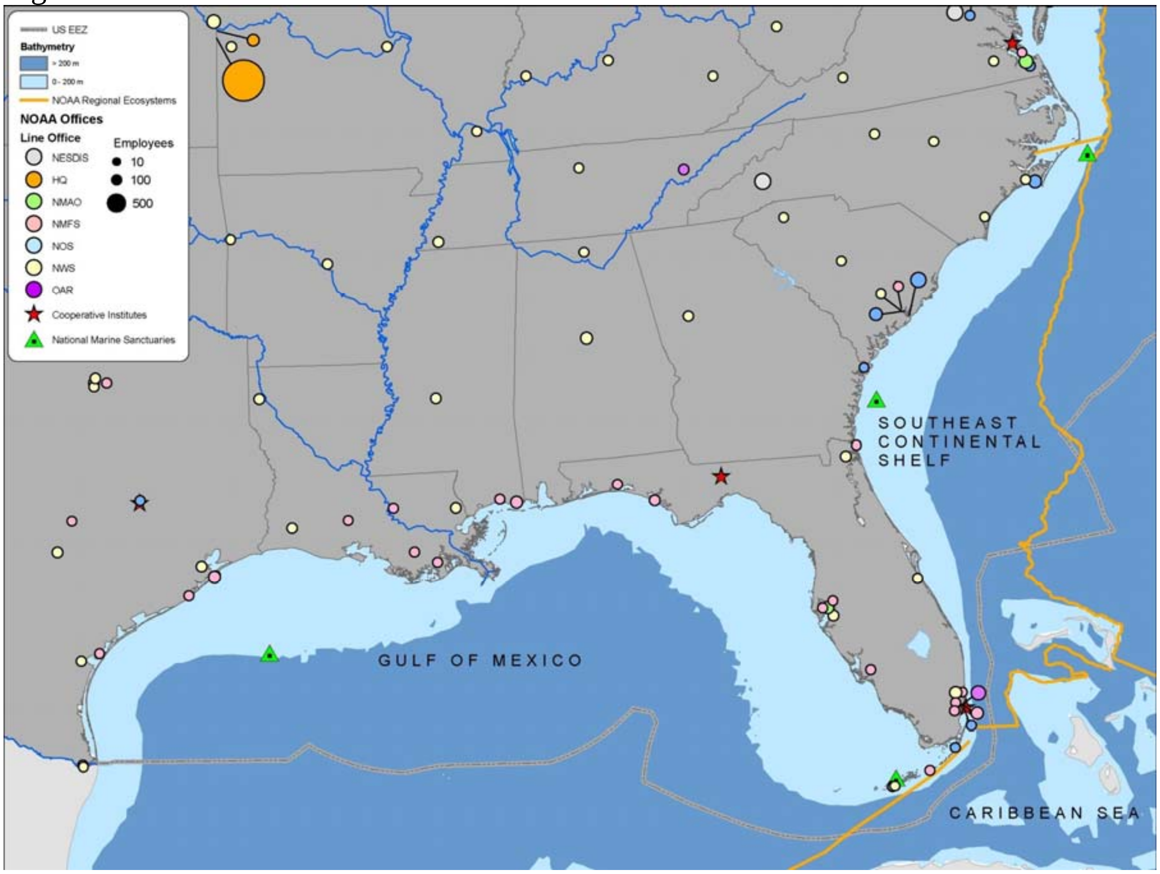
Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. Boundaries of the large marine ecosystem are given (yellow line).

Figure II.C.8. Location of NOAA offices in the Northeast and Western Continental USA, by line office



Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. Boundaries of the large marine ecosystem are given (yellow lines).

Figure II.C.9. Location of NOAA offices in the Southeast



Source: Mike Ford, NOAA. Symbols are size-scaled by number of employees. Boundaries of the large marine ecosystems are given (yellow line).

II D Policy Trends and NOAA's Vision for the Future

The Ecosystem Goal Team has articulated a long term vision for its activities (http://ecosystems.noaa.gov/docs/EGT_Poster_Handout_03.29.05_v2.pdf) that transition from the management of various components of coastal and marine ecosystems and trust resources, to management founded on the interrelated nature of societal needs and ecosystem goods and services. Specifically, NOAA's vision for ecosystems includes ecosystem approaches to management which are collaborative with more diverse groups of stakeholders, and progresses incrementally and adaptively as new information and greater willingness to engage occurs among sectors. NOAA's vision includes specifying ecosystems geographically (on multiple scales depending on issues being considered), accounting for uncertainties and multiple influences on ecosystem outcomes, and balancing diverse stakeholder needs when making management decisions regarding the marine environment.

The six white papers (Appendix 3) develop parts of this vision more completely for a few key activities. All six emphasize that issues once thought of as being confined to a single sector of users will enter into more complex negotiations among multiple sectors, informed by natural and social science capabilities. Climate change will have increasing impact on the productivity and distribution of marine and coastal species. Consequently, management programs will have to adopt approaches that adjust to changing productivity regimes, and are sensitive to the spatial re-distribution of benefits. Living resource management will increasingly focus on tradeoffs among resources linked by trophic and technological interactions. Increased human uses of fresh water will challenge our ability to main estuarine and coastal habitats and species dependent on flowing fresh water ecosystems, including anadromous fishes, and brackish water dependent species. Competing uses of coastal areas for living resource uses, energy and mineral extraction, recreation and other activities will accelerate and require more explicit allocation of activities to specific areas. Marine zoning as a management tool to allocate space will require new types of science and greater detail in observations. Improved forecasting of a variety of marine phenomena will be needed to support more timely and comprehensive management of marine activities. Surrounding all of these issues will be a need for more formal and integrated marine governance institutions and a social science context for making allocation decisions across the many and diverse stakeholders in the marine environment. This will require increased emphasis on socially relevant outcomes, analysis of policy options, and emphasis on multiple value systems, including non-consumptive uses. The white papers emphasize that NOAA will have to expand its science capabilities to serve these and other pressing ecological issues. These themes help set the 'guiding considerations" formulated by the eETT below in Part III.

Our report assumes that NOAA will continue to meet its statutory responsibilities consistent with its enabling legislative mandates (Table II.A.1). However, it as necessary to look at emerging policy as an indicator of the direction NOAA might be driven through legislation. In the near term, bills are pending in Congress for a NOAA "Organic Act," and for reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act, Marine Mammal Protection Act and Coastal Zone Management Act (www.thomas.loc). Considerable discussion about whether or not Congress should direct NOAA to adopt an ecosystem approach through a legislative requirement expanding its various mandates is taking place. It is unclear how each of these efforts will play out or could affect the pace at which NOAA develops an ecosystem approach to management.

The administration's Ocean Action Plan sets in motion the potential for high level coordination among federal agencies. Recent reviews by members of the Pew and US COPS give low marks to the administration and Congress for implementation of the US Commission on Ocean Policy recommendations thus far, but the direction of change is not contested.

Developments at the state and regional ocean governance level are also fostering wider adoption of an ecosystem approach to managing human activities. Nine coastal states have passed ocean policy legislation, developed ocean advisory councils or have shown significant new interest in ocean affairs. In addition, some well established regional ocean governance efforts like the Gulf of Maine Council on the Marine Environment, the Great lakes Regional Collaboration, and the Southeast Aquatic Resources Partnership have been invigorated and discussions are taking place among Gulf of Mexico and West Coast governors. NOAA ecosystem science supports each of these efforts. NOAA has asserted a leadership role in the development of a Chesapeake Bay Fisheries Ecosystem Plan gaining traction among coastal states and other efforts, such as developing a Puget Sound research plan are underway with strong NOAA support.

Looking more broadly around federal agencies, especially those with primarily terrestrial land management (e.g. US Forest Service, US National Park Service and the US Fish and Wildlife Service) ecosystem approaches have been under development for a much longer time, The Fish and Wildlife Service actually attempted to organize its administration around a regional ecosystem concept where significant local autonomy was given over tasking and budgeting by ecosystem areas. For various reasons, primarily bureaucratic and budgetal, the experiment did not prove to be successful and the Service has retreated to its more traditional organization with central administration dealing with allocation of financial and other resources.

In the arena of private non-governmental organizations, there is significant interest in developing ecosystem approaches. Funding and human resources have been assigned to developing scientific research, education and communication of scientific results, development of inventory methods for species and habitats and, in some cases, linking these to patterns of use. NGOs are pushing to accelerate the pace of change through litigation and driving political advocacy for legislation.

The contemporary environment for transition to an ecosystem approach may appear chaotic. Many initiatives are underway and many different approaches are being tried. Some of these initiatives are top down and some are bottom up. NOAA's efforts have elements of both. Differences in geographic scales of initiatives, in perception of issues and, in who is involved in the discussions all contribute to the diversity of approaches being attempted. **There is not a convergence on a single ecosystem approach "end product" but growing realization that the likely way forward will be a an incremental and adaptive process as current approaches to management take on more complex elements involving multiple drivers and issues.** For example, fisheries management activities under the Magnuson-Stevens Act are being used to address more diverse societal goals and outcomes. In several areas of the country, essential fish habitat provisions are being used to conserve deep water corals and other unique habitats. As well, protected species management is being integrated more fully into coastal zone management, sanctuary and other management venues supported by NOAA under its diverse mandates. Clearly ecosystem approaches are already being implemented in NOAA's science and management, and will expand. The uncertainties are about how and how fast the transition occurs.

Our report focuses on how NOAA might transition its ecosystem activities to facilitate these inevitable changes. Overall, while the integration of the ecosystem science enterprise is far from complete, and substantial capacity gaps exist, it is appropriate for NOAA to provide more integrated science in the existing venues now. The eETT does not expect that a single direction for adoption of an ecosystem approach will emerge quickly, although valuable lessons are accumulating nationally and internationally. Beyond question, however both natural and social sciences, including communication of science are critical elements at whatever scale and for whatever purpose ecosystem approaches are being developed. NOAA is already positioned to play a central role in provision of scientific support to multiple parties. To keep pace with growing demands of government and society, however, NOAA must expand and integrate its capacity for the ecosystem science enterprise. This Report is intended to advance that task.

PART III GUIDING CONSIDERATIONS

From the context outlined in Section II, within which NOAA must be prepared to operate with efficiency and excellence, the eETT identified three Guiding Considerations from which the findings, conclusions, and recommendations flow. Specifically:

- NOAA science and management needs to take account of environmental forcing on the ecosystem properties for which it is steward,
- NOAA science and management needs to take account of how human activities affect the ecosystem properties for which NOAA is steward – and how those ecosystem properties affect the wellbeing of citizens socially, economically, and culturally, and
- Because of the two preceding points, NOAA science support for decision-making must be integrated across ecosystem components and across its role supporting management of different human activities.

In addition, transition within government always must address a variety of realities that affect the ease and pace of change. Some of these are institutional, some legal, and some related to the need to change expectations and established practices of both those being served by the agency and those providing the services from within the agency. The findings, conclusions, and recommendations must not ignore these realities along with education and training, if the transition is to be successful.

III A Environmental Forcing

A key part of an ecosystem approach to management is taking account of the effect of the physical and chemical environment on biological communities and the implications of this forcing for sustainability of human activities in marine ecosystems.

The environment directly impacts marine ecosystems in three general ways:

(1) The foundation of most of the marine food web is primary production in which chemical nutrients and dissolved carbon are converted through photosynthesis into organic material. Ocean currents, upwelling and near-surface ocean mixing are among the physical processes that affect the availability of nutrients and atmospheric variations of cloud cover and haze affect the availability of solar radiation.

(2) The biology of marine animals is affected directly by environmental characteristics such as temperature, bottom type, frontal activity, etc. Consequently, when the environment varies, the mobile parts of the ecosystem move and all elements potentially thrive or suffer.

(3) Chemicals, sediment and microbes introduced into the ocean, particularly along the coast, have impacts on the health and productivity of benthic and pelagic ecosystems.

Additionally, the ecosystem affects the environment particularly through the carbon and radiation budgets that determine the earth's climate. Variability of the global climate (phenomena like the ENSO cycle or the North Atlantic Oscillation) includes coupled ocean-atmosphere processes that change the circulation, temperature, and physical processes that supply nutrients to the ocean. Correspondingly biological time series show substantial changes in the abundance and species composition of marine ecosystem linked to these ocean-atmosphere linkages. El Niño cycles have large and somewhat predictable consequences along the U.S. west coast; the North Pacific Oscillation has equally large impacts along the west coast and around Alaska, whereas the North Atlantic Oscillation impacts ecosystems throughout much of the North Atlantic. Smaller and less sustained variations have equally strong but more localized and transient impacts. If climate forcing of ecosystems is to be accounted for in managing marine resources and ecosystems, research in two broad areas is needed: **(1) knowledge of the structure and dynamics of climate variability <u>in the ocean</u> must be increased so that observed ecosystem changes can be properly attributed to its causes and eventually predicted and (2) the mechanisms by which environmental forcing affects different biological communities must be better understood in order to identify management strategies which accommodate them appropriately.**

III B Role of Human Actions

Society reaps tremendous benefits from the oceans, coasts, and Great Lakes. The economies of coastal watersheds accounts for half of the US gross domestic product and 60 million jobs. The human activities that generate these benefits include marine transportation and trade, fisheries, tourism and recreation. These activities draw people to settle in and visit our coastal areas, making them increasingly crowded. In 2003, 53 percent of the US population lived in coastal counties, a zone that comprises only 17 percent of the total US land area. Twenty-three of the 25 most densely populated counties are on the coast, and average 300 persons per square mile. In addition, there is growing demand to use living marine resources and to produce energy and minerals from offshore deposits.

The growth and settlement of populations in the coastal zone, in conjunction with the associated economic activities constitute a set of major forcers on coastal and ocean ecosystems. Humans' activities often lead to, inter alia, the degradation and loss of natural habitats, added waste disposal and pollution discharges to water bodies, over exploitation of living marine resources, invasive species, pathogens, toxic contaminants, and harmful algae blooms; and increased vulnerability to coastal hazards. In recent years, nearly a fourth of the estuarine areas were unsuitable for swimming or fishing; and there were 18,000 days of beach closings and advisories issued in 2003 due to high bacterial counts.

Non-point source pollution has increased as human activities have grown in coastal areas, causing nutrient enrichment, hypoxia, harmful algal blooms, toxic contamination, and other problems that plague coastal waters. Land use practices may increase sediment loading in the nearshore zone, impacting the amount of light available for benthic communities. Atmospheric transport can result in deposition of pollutants far from their sources. Problematic point sources of pollution include sewer system overflows, septic systems, wastewater treatment plants, animal feeding operations and industrial facilities – all of which are the products of major economic activities. Point and non-point source pollutants are introduced directly into the coastal ocean and favor the growth of some marine species while harming others. Some of these effects are well understood (e.g., nitrate-rich runoff from agricultural activities stimulate phytoplankton growth) whereas others are not (e.g., viruses in sewage treatment outfalls that can be transmitted to marine species).

There are global impacts as well; it has been suggested that rising carbon dioxide concentrations in the atmosphere will eventually lead to river temperatures that are too high for Pacific salmon or increase ocean temperatures that will cause coral bleaching. In addition, the overexploitation of fishery and other living marine resources continues for over a fourth of the stocks that have been assessed. Noise in the coastal ocean may alter the behavior of fish and marine mammals that rely on acoustics.

In all of these examples, an ecosystem approach to management must address the full impacts of both local and global human activities in order to develop effective policies. In light of these conditions, the US Commission on Ocean Policy (USCOP 2004) expresses the concern that:

> *Our failure to properly manage the human activities that affect the nation's oceans, coasts, and Great Lakes is compromising their ecological integrity, diminishing our ability to fully realize their potential, costing us jobs and revenue, threatening human health, and putting our future at risk.*

III C Integrative and Scientifically Informed Management and Policy

Management agencies at all levels of government acknowledge that scientific advice is an important input to management and policy, although the processes by which they obtain such advice and information vary widely. The Trends noted in sections II C and D, and the Guiding Principles in sections II A and B all argue that the dependence of management and policy on science advice can only increase in future. Moreover, even if management itself is not integrated, by placing management of each human activity in the context of the relevant ecosystem forcers and all the effects of each human activity on the ecosystem, advice provided to one client on one management or policy issue will necessarily include some considerations also addressed in advice to other clients on other issues. Thus, not only will users become more dependent on the ecosystem advice developed by NOAA, provision of such advice will become more complex.

NOAA produces high quality science research and advice for management. However, the benefit to management from understanding and accepting scientific information and advice varies in several ways. The role of environmental forcers on ecosystem dynamics varies regionally and at different spatial scales. Various human activities being managed are affected differentially by the environmental forcers, and have different magnitudes of impact on the ecosystems being managed. Even the culture of managers and decision-makers to seek and apply science advice varies among regions and industry sectors. All these considerations will affect how NOAA's ecosystem science best supports management and policy, but none negate the growing need for such support and education. Moreover, as the advice to each user addresses more ecosystem considerations, it will have to be consistent with advice provided to all the clients of similar regional scale. Inconsistencies would damage both the credibility of the advice itself and the effectiveness of any decisions based on it.

Thus, the scientific enterprise must be mindful of basic and applied management and policy, and oriented to support decision-making. Advisors to different clients must communicate effectively with each other, and often encourage those receiving the advice to communicate as well. The advice must be packaged at the scale appropriate to the local or regional management body, and must be perceived as non-partisan by competing interests in the management issues. NEPA compliance is a critical aspect of the formal advisory process, requiring both disclosure of environmental impacts (including cumulative effects) and measures to mitigate such impacts. Thus, NEPA requires consideration of ecosystem forcers and impacts for specific federal actions, as a stepping stone to broader application of an integrated ecosystem approach to managing human activities in marine ecosystems.

The kind of NOAA science enterprise that is recommended in our report takes into account the current situation and proposes an integrated ecosystem assessment as the foundation for provision of science support for management and policy, regardless of NOAA mandates. The favored approach allows all participants in a management process to have access to and input into the development of scientific advice for management yet ensures that the provision of scientific advice is policy relevant without being policy-directed. Effective advisory processes can allow significant interactions between the scientists and the interested parties so that there can be learning about the scientific basis for all options, while preventing management and stakeholders from influencing the science results and advice.

III D Transition Realities

NOAA is in a difficult position. It cannot implement an ecosystem approach to management overnight even if given such an improbable mandate. More realistically, transition toward EAM must be seen as a process already underway (Section II-C) that must continue in the longer term. Making a transition towards EAM is a process akin to turning a large ship – inertia must be overcome without compromising stability. Absent a crisis or strong legislative mandate and facing limited resources, change can only come by constant pressure applied in the direction of the turn. In NOAA this pressure is being applied by leadership at top and by experts throughout the agency, as seen in production of integrated assessments, etc. Reprogramming of missions and resources are incrementally turning the NOAA approach. Of course, many things may affect this, including future budgets, potential litigation and legislation, and extent of public support.

It is unhelpful to speculate on future budgets and future litigation. However without strong support from both direct clients of the NOAA ecosystem science enterprise and the general public for the changes proposed in the rest of this Report, both budgets and litigation could impede transition. The directions of change outlined in this Report fit well with the visions promoted in the US Ocean Commission and Pew Reports, providing a foundation for “selling” this vision of NOAA’s ecosystem science enterprise to both the public and NOAA’s clients. Such a “selling” is necessary, because it will not be possible for NOAA to sustain a credible ecosystem science enterprise, and support mandates with science advice in an ecosystem context, without significant increases in resources. Care must be taken, though, to ensure that the public and especially clients of NOAA ecosystem science understand that the support they will get in future may be different from the support that they have gotten from NOAA in the past. Close cooperation with the clients will be needed so they can continue to fulfill their own missions and mandates, and taken advantage of the changes in support from NOAA to make appropriate changes in their own activities, to make more integrated management in a broader ecosystem context a reality.

NOAA experts need to see their own role in this new ecosystem science enterprise as well. Throughout our interviews with NOAA staff we found strong support for a greater ecosystem focus for NOAA science. This is another important foundation on which to build. To keep that support, however, it will be necessary to ensure the staff members are part of the process of change, rather than just some of the “objects” which moved around by others.

For a large multifaceted agency like NOAA, it is difficult to achieve universal support for this broader vision because different constituencies have greater affinities with different parts of the agency. Their demands for support tend to focus narrowly on their needs to the exclusion of support for a more synthetic and integrated organization and many inside the agency perceive their role as serving a particular constituency. Thus, in the short to medium term it is critical to focus within NOAA on creation of an ecosystem culture and to communicate and function with a consistent ecosystem approach.

PART IV CONCLUSIONSS AND RECOMMENDATIONS

Based on the context and guiding considerations, the eETT deliberated at length on the changes needed, if any, to positioned NOAA’s ecosystem science enterprise to deliver its mandates in the future. Part IV presents our conclusions and the reasoning used in reaching them, as well as recommendations to guide NOAA towards the kinds of change required to support an ecosystem approach to management. Our approach is to discuss the scientific rationale for each change, provide a simple declarative statement of our conclusion, and possibly make one or more recommendations about what needs to be done. Where a conclusion warrants illustrations or more extended discussion of factors to consider, these are included in text boxes.

IV A An Ecosystem Approach is Appropriate Now

Through its Ecosystem Goal Team, its 5-year plan and 20-year vision, and the contributions of its many staff, NOAA clearly recognizes and has set a direction moving towards a more integrated, ecosystem-based approach to its science and management activities. The transition is

> **Text Box. Current evolution towards an ecosystem approach to management in NOAA**: Fisheries management activities under the Magnuson-Stevens Act are being used to address more diverse societal goals and outcomes. In several areas of the country, essential fish habitat provisions are being used to conserve deep water corals and other unique habitats. As well, protected species management is being integrated more fully into coastal zone management, sanctuary and other management venues supported by NOAA under its diverse mandates. Thus, one can argue that ecosystem approaches (or at least elements of EAM) are already being implemented in NOAA's science and management.

not a paradigm shift, but rather a continuum as current approaches to science and management take on more complex elements involving multiple drivers and issues. There are tremendous potential efficiencies and synergies in adapting observing systems to collect multiple trophic and physical data attributes, and these will be increasingly important in evaluating options for human uses of ecosystems. Likewise, restructuring its tremendous data holdings now to allow more integrative ecosystem science will have greater payoffs in the future. Integrated science initiatives such as FOCI in the North Pacific and GLOBEC in New England have already demonstrated the feasibility and value of integrated ecosystem science. Thus, although the integration is only partially complete, and substantial data gaps exist, it is appropriate for NOAA to provide more integrated science in the existing venues now,

Conclusion 1 NOAA's emphasis on an ecosystem approach to its science and management activities is timely and appropriate.

IV B NOAA Must Provide Leadership for a Collaborative Approach

A new emphasis at the Federal level on coordination of ocean activities reflects the calls in the Ocean and Pew Commissions for more integration of diverse activities distributed over a large number of agencies (see Text Box). This collaboration needs to be extended to NOAA's own

<u>Text Box. Interdepartmental coordination of marine ecosystem science and management in the Federal government</u>: As a result of the adoption of the US Ocean Action Plan the Federal government has committed to enhancing inter-agency coordination of its ocean activities. Under the White House Committee on Ocean Policy (COP: http://ocean.ceq.gov/). A number of committees have been created to enhance ocean science and technology, and to coordinate resource management activities. The Joint Subcommittee on Ocean Science and Technology is comprosed of over 16 agencies, with co chairs from NOAA, NSF, and the White House Office of Science and Technology Policy. The Subcommittee on Integrated Management of Ocean Resources (SIMOR) is jointly chaired by NOAA, CEQ, DOI, and EPA. Additional subcommittees have responsibility for science integration with management activities, and for coordination. Because of its scope and size, NOAA plays a leadership role in these and many other ocean-related activities.

elements, and to its many and diverse stakeholders. Greater collaboration among ocean science and management activities is a cornerstone to any ecosystem-based approach because no one entity has or will have all the diverse resources necessary to address the wide range of relevant activities. Moreover, collaboration with and among stakeholder groups is a key element in managing the many and conflicting activities in marine and coastal ecosystems. NOAA has a unique role to play in formulating and implementing a collaborative approach and in exerting leadership because of the diversity of its mandates. By articulating a set of principles related to necessary collaborations for EAM, and effectively implementing them in its own sub-agencies and with its stakeholders, NOAA can lead other elements of government to do the same.

Conclusion 2 NOAA must be prepared for leadership and implementation in an open, inclusive and collaborative structure (both internally and with external partners).

Text Box. Examples of expanding mandates from Congress: Programs in the North Pacific have been funded to examine the implications of the loss of sea ice on the ecology of living resources. Socio-economic analyses of the impacts of federal regulations are required for all federal management activities. Additionally, funding has been provided to study factors responsible for coral bleaching and loss of coral habitats. Habitat analyses supporting management of a wide variety of living resources are supported in law. There are numerous other examples wherein Congressional direction means that ecosystem principles are being applied to understand and manage the marine environment.

IV C An Expanded Scope for NOAA's Research Will be Needed

All of the science enterprise currently part of NOAA's ecosystem portfolio had their genesis in some authorization by Congress to expend these funds for a particular purpose, e.g., fisheries assessment, coral reef assessment, marine mammal assessment, monitoring in sanctuaries, coastal zone monitoring, etc. Over time Congress has amended many the laws that NOAA administers to incorporate wider arrays of issues known or suspected to be affecting its trust resources (see Text Box). The totality of these expanding mandates is a clear recognition, if not yet in name, that ecosystem approaches to analysis and management of marine areas is required.

NOAA too is expanding from its traditional line office orientation to undertake cross-line programs that are best organized and undertaken at the regional ecosystem level (See Appendices 4 and 5). Regionally, the need to incorporate broader ranges of information in management and policy have led to these ad hoc and more formal collaborations among NOAA elements and between agencies and academic institutions. This is because no one entity has the necessary resources to work in all of the required areas, and there are insufficient resources in NOAA to allow redundant capabilities. The EGT and PPBES process appear successful in identifying where strategic collaborations could address joint priorities. For years, such collaborations have existed in the field, as individual researchers identified the need and possibility of collaborations (Appendices 4 and 5). These collaborations need to be fostered and expanded at all levels (national, regional, and laboratory) to match NOAA's capabilities to the expanded science support required for more integrated approaches to ecosystem management.

Conclusion 3 Programs within NOAA's ecosystem science enterprise were originally designed to meet individual mandates and are expanding their scope to meet ecosystem management requirements.

IV D A Plan for Achieving an Ecosystem Approach is Needed

As illustrated above, the science, assessments, and advice supporting current management and regulatory responsibilities of NOAA as well as the many other clients of NOAA science are being provided within broader ecosystem contexts. These are incremental changes; usually done by adding new factors to approaches that were "business as usual." Perhaps additional parameters or functional relationships were added to a stock-assessment analytical model to capture the influence of an environmental forcer or key predator; perhaps the advice was expanded to estimate the bycatch of a key species at various effort levels in a fishery targeting another species.

Although examples of such changes can be found in almost all the major assessment and advisory activities of NOAA, in even the best examples this increase in scope of the sector-specific science advice is still in the early stages and much remains to be done. Even those promoting the incremental broadening of assessments of individual ecosystem components or of sector-specific advice on the consequences of a human activity have no clear ideal how far this journey of individual incremental steps will go. This incomplete vision of what the final product will look like – the adequate number and type of ecosystem increments to an assessment or advice on an activity - is understandable because globally the scientific community is learning by doing. It is premature to make definitive statements about how much ecosystem content is "enough" in the support provided to the clients of NOAA's science. However, it is also impossible to plan or organize for a successful future without a clear vision of what success looks like.

In order to guide development of an adequate research basis, NOAA should develop an explicit description, based on current knowledge, of what it sees as adequately "ecosystem rich" assessments and advice. This does not have to require specifying exactly which ecosystem forcers and species interactions to include in assessments, or exactly which ecosystem impacts of individual human activities will be considered in advice. It does require being explicit about the criteria that are to be used to select the forcers, interactions, and impacts to include, and the criteria to be used to decide which relationships are worth including as increments to “business as usual”. It also requires using the current knowledge of where current assessments and advice fall short as bases for informed management, of where current knowledge is underutilized in assessments and advice, and what current uncertainties and unknowns will be addressed by research currently “in-stream.” The uncertainties may not be eliminated in the more ecosystem-rich assessments and advice, but at least they should be captured explicitly and dynamically. This description should include the major incremental steps that can be foreseen at present and an expected timeline for being able to take these steps.

Descriptions of how much ecosystem content will be needed for the incremental augmentation of assessments of individual ecosystem components and of the advice on regulating individual human activities should be developed for all NOAA Line Offices concerned with ecosystems, not just NOAA Fisheries. Although it may not be possible, or a good use of time, to prepare such an ecosystem developmental plan for each individual activity (each stock assessment; each sanctuary), the greater the level of disaggregation in the planning, the more informative the exercise would be. Brought together, these descriptions should determine where NOAA science must evolve to support the current incremental approach to “business as usual” within each Line Office and the Ecosystem Goal Team.

Conclusion 4 NOAA should develop an explicit description, based on current knowledge, of what it sees as adequately “ecosystem rich” assessments and advice for the current products of its ecosystem science enterprise.

Recommendation 1: At the finest scale of disaggregation that is practical, NOAA should prepare an “ecosystem development plan” for its assessment and advisory activities. These plans would lay out the major incremental steps foreseen for increasing the ecosystem content of these activities, and the expected timelines, in a proactive but not proscriptive manner.

Recommendation 2: When the individual “ecosystem development plans” are completed, they should be assembled into an overall vision of where NOAA ecosystem services and science are going. This consolidated plan should be an informative basis for analysis of both gaps and redundancies, and provide insights into the similarities and differences in what different Line Offices see as “the ecosystem approach”.

IV E Regional Coordination Across Line Offices is Needed

Looking across NOAA’s ecosystem enterprise, the most important unmet need is coordination of NOAA’s ecosystem science for management activities regionally across LOs and with external partners. Line Offices expanding the scope of their activities will not, in itself, produce integration of ecosystem-based science and management activities. Essentially all of NOAA Line Offices and NOAA’s partners have expressed the intent to place their management and regulatory roles on an ecosystem basis. To do so, obviously each agency needs to consider the human activity that it manages relative not to the natural dynamics of the ecosystem in its pristine state, but relative to the ecosystem as it has been altered by past and current human uses. From that perspective, it follows that a successful ecosystem approach to management must view the management of human activities in an integrated way. It is not enough to manage each sectoral activity in a broader ecosystem context without consideration of any other management activities or plans for other sectors. Each management activity in an ecosystem may affect the success of every other action. The linkages between the consequences of management choices in different sectors makes integrated management a necessary companion to adopting an ecosystem approach to sector management.

This necessary partnership between sector and ecosystem approaches does NOT mean that the actual management agencies must be integrated in terms of jurisdiction and authority. It DOES mean that their planning strategies and management choices have to be conducted in full knowledge of the options being considered by the other agencies that manage human activities with potential to affect the shared ecosystem. It also means that the various agencies need to start from a common factual basis for accommodating the effects of various natural and human forcers, and for evaluating the consequences of all the human activities in the shared ecosystem. Without full information sharing among agencies in planning and choosing management options, individual sectors may be led to prefer alternatives that would be optimal were that activity the only use of the area, but which fail to be sustainable or to provide the expected benefits due to the consequence of other activities in the same area. Without a common scientific basis for accommodating forcers and evaluating ecosystem effects of human activities, the choices made in one sector can thwart achievement of the management goals of another sector.

Text Box. Approaches to advisory support to multiple clients of “ecosystem advice: One way to coordinate the science advisory basis for different management activities is to provide a “single window” for ecosystem science advice to all the clients supported by NOAA’s ecosystem science enterprise. The single advisory source could maximize the compatibility of science support provided to all clients, minimize the redundant work necessary to provide the needed advice to all clients, and allow for most effective planning and priority-setting. Alternatively, NOAA could provide a specific coordination function, laid on top of existing sector-oriented advice givers (e.g., Fisheries Science and Statistical Committees and Marine Protected Area Committees) to share information, plans and goals between groups informing different sectors. Although this approach may not achieve the efficiencies and compatibility of science support possible from a single entity tasked with providing integrated science advice, it may be easier to implement in the short term. These options need to be discussed with all Line Offices, federal, state and local agencies concerned with, or able to support, coastal and marine management, regulation and policy, and a strategy developed.

The results of the “ecosystem development plan” analysis called for in IV-D needs to be considered in the context of the imperatives to integrate planning by management and regulatory agencies and industries, and to develop a common view of ecosystem status and dynamics shared across agencies. There is little cause to expect that incremental but independent development of component-specific assessments and sector-specific advice will converge on a consistent view of ecosystem status and dynamics, and provide all the information that each management sector needs to know about the activities and effects of the others. Hence, it seems that some form of Integrated Ecosystem Assessment at regional scales will be a necessary step as NOAA and its partners move to an ecosystem basis. Likewise integrated priority setting for the science support needed from NOAA will be essential. An incremental broadening of the scope of the assessments and advice supporting individual sectoral management will be not lead to such integrated assessments. They have to be planned and produced as an activity in themselves.

Conclusion 5 The preferred option for coordinating the ecosystem science enterprise is to maintain the Ecosystem Goal Team with its overall national mandate, but establish ecosystem coordination teams to coordinate Line Office activities at the scale of the eight LMEs.

Recommendation 3: NOAA management should commit to supplying ecosystem-science support on a regional basis. This will require collaboration between Line Offices and other agencies to coordinate science and management activities in several sectors. As a preliminary step, NOAA should organize a forum for all Line Offices, federal, state and local agencies concerned with, or able to support, coastal and marine management, regulation and policy. Objectives would be sharing information and plans, developing a common scientific basis for management, and building cooperation between organizations.

IV F Integrated Ecosystem Assessments are a Useful Framework for Coordination

Integrated ecosystem assessments (IEAs) are an effective vehicle to convey information on the status of ecosystem health and to evaluate the impacts of current and proposed stressors (See Text Box).

Text Box. What is meant by an "integrated assessment?" Integrated ecosystem assessments (IEAs) are a tool to bring information sources together – organized geographically and supporting a diverse set of stakeholder needs. Ecosystem assessments are intended to do the following:

- Compile and archive all relevant data sets for a defined ecosystem, including physical oceanography, atmospheric climatological and weather observations, human use patterns and statistics, abundance and distribution of biological resources.
- Report on current conditions and trends in relevant data time series of physical, biological and human use information
- Synthesize time series information to link important ecological outcomes to changes in relevant climate and human use drivers, as a basis for forecasting
- Evaluate data time series to provide suites of key indicators of ecosystem state (status), and utilize time series data and modeling results to propose reference levels for the desired state of marine ecosystems
- Forecast the relationship between state indicators and pressure indicators (e.g., pollution, climate change, fishing-related removals, coastal development, etc.) in order to inform the development of management options for marine ecosystems.
- Provide periodic ecosystem assessment updates to inform the managers, stakeholders and the public on the state of marine ecosystems and management options to achieve societal goals and targets, including social science aspects relevant to decision making.

Typically, NOAA, and other marine science/regulatory agencies, provides "state" and "pressure" indicators and forecasts individually for each component in their marine management portfolios. Protected species assessment updates or fisheries stock status updates, for example, would be provided separately, sometimes with relevant oceanographic conditions updates and sometimes not. IEAs seek to compile, analyze and report information relevant to multiple stakeholder (sectoral) interests. Since IEAs are provided for a specific geographic entity, various observations appropriate to that geography are integrated and synthesized. Place-based observations obtained from areas such as marine sanctuaries, estuarine reserves, buoys and ship-board measurements can be combined with and compared to synoptic observations combined from the large marine ecosystem in which these places exist. Thus, changes at these specific locations can be compared to the relevant trends in the ecosystem as a whole.

The integration should reach all the way to the observations which lie at the base of ecosystem assessments. NOAA collects a wide variety of physical, biological, economic, and social information to fulfill its various statutory responsibilities. Historically these data were obtained to meet specific mission drivers and support management or stewardship activities. The importance of linking observations has increasingly been recognized, leading to the provision of suites of data necessary to interpret complex interactions among physical and biological processes. Evaluating the ecosystem impacts of climate variability and change, for example, have led to integrated programs in all marine ecosystems where NOAA has responsibilities. Data sets developed to meet NOAA's various missions provide the basis to determine the status of the physical environment or regulated species, but it is the integration of these measures that allows an assessment of the ecosystem as an entity. Efforts to provide integration are implicit in NOAA's entire ecosystem enterprise, but these efforts are not coordinated and thus appear to reflect regional or individual line office interests or priorities rather than a corporate NOAA approach.

ecosystem science support for management and policy has several advantages over relying on the incremental expansion of component-specific assessments and sector-specific science support in order to converge on an integrated ecosystem approach. Inherent in conducting an integrated ecosystem assessment is devoting greatest effort to assessing the status and trends of those components of the ecosystem (including humans) most important to its integrity. Features important to specific human uses which NOAA is mandated to regulate also receive direct attention in the integrated assessments.

However, these features are viewed relative to the overall ecosystem status and trajectory, giving the desired ecosystem context for regulating human uses of aquatic ecosystems. This approach contrasts with incremental expansion of assessments of the specific ecosystem pieces of greatest commercial interest (see Text Box). Both allocation of science resources and quality of the science products are better when the assessment focuses first on the ecologically most significant features and works outward towards the components of the ecosystem where statutes or regulations require additional directed evaluation.

Text Box. Short-comings to incremental sector-specific approaches: A solely incremental approach by separate LOs has three shortcomings. It poses a high risk of gaps in treatment of structurally or functionally important parts of the ecosystem, which receive little attention because they are not being used directly. Even "incremental approach" is required to add all ecosystem components that are structurally and functionally most important, they will be viewed not in the context of the ecosystem but in terms of how they affect the parts of the ecosystem being used directly. This may give quite incomplete and biased views of the dynamics of the ecologically most significant ecosystem components, thereby reducing the effectiveness of the pooled "incremental assessments" as a source of insight into the state of the ecosystem and how it is being affected by human uses of it. It his a high risk of creating redundancies, as different LOs will necessarily have to address some key features of marine ecosystems. Planning independently, a LO might be aware of relevant work in another LO, but still feel it needs to do overlapping work because it comes at the ecosystem property from different perspectives. Most seriously, it has high risk of resulting in inconsistent science products across LOs. Even if a number of component-specific assessments independently add the same ecosystem features because they are crucial to the structure and function of the ecosystem, a reconciliation of all these partial views would still have to be undertaken. Depending on the slants taken independently in the incremental assessments, the reconciliation of a variety of views with different biases may be difficult to achieve.

Providing information through IEAs is not only more efficient than compiling all assessments sectorally, but also allows for scientific integration and exploration of alternative hypotheses for observed changes that may be difficult if assessments are done individually. Compilation of IEAs is inherently multidisciplinary and implies collaboration across Line Offices and with other agencies. The process of developing IEAs requires a governance system that fosters such collaboration, since rarely does one agency or entity have all the information and expertise required. Importantly, bringing diverse stakeholder groups together to consider tradeoffs inherent in making marine resource management decisions can be facilitated through the production of IEAs that contain stakeholder-relevant information as well as outcomes for the various sectors and interests under alternative management scenarios. Hence producing IEAs will provide a specific focus for ecosystem efforts, fostering multi-agency approaches to priority setting in accomplishing shared and individual agency mandates.

Conclusion 6 Integrated Regional Assessments are key components of NOAA's ecosystem science enterprise. Their production should be priority for NOAA and its science and management partners.

Recommendation 4: NOAA's Ecosystem Goal should lead and participate in the development of Integrated Assessments (IEAs) for all ecosystems in which NOAA has a statutory or trust responsibility. Where possible NOAA should use other multi-agency venues, including its participation in the Integrated Ocean Observing System (IOOS), to foster the production of IEAs.

IV G Integrated Assessments and Management Must Be Spatially Based

Integrated Ecosystem Assessments and Integrated Management approaches are inherently spatially based and require identifying scales at which they will be conducted. Classical assessment approaches usually considered individual populations integrated across their full range of occurrence, with little attention to spatial pattern within the range. This sufficed when the main goal was simply protection or sustainable harvesting of individual populations. Assessments in an ecosystem context begin with the spatial area of interest, and the system components within that area (populations, physical/chemical systems, human activities, and the corresponding interactions among these) are identified from the start. An assessment may still estimate the status and trends of selected ecosystem components in the area, such as exploited fish species, as important products. However the integrating aspect of the assessment is the area wherein the ecosystem components interact.

The eight regional Large Marine Ecosystems (LMEs) defined by NOAA appear suitable starting points for coordinating regional ecosystem science and assessments. These ecosystems have direct correspondence to the Fishery Management Council activities, which NOAA must continue to support as one of its primary responsibilities. The regional control and management of activities will remain a key paradigm of future integrated management.

Not only must relationships and patterns of ecosystem components be considered on the region scale, but often ones at finer scales are of interest as well. Examples of these finer scale issues include local depletion of managed and unmanaged fish populations, effects of human activities on local coral habitats, interactions of fisheries with sea lion and bird populations, and estuarine effects of human activities. Integrated Ecosystem Assessments must be designed so finer-scale resolution of trends and interactions can be extracted when needed. The ability to scale the regional assessments down (and occasionally up) to management applications on finer scales will be important to client satisfaction with this approach.

Conclusion 7 The eight LMEs defined by NOAA are an appropriate scale for the integrated regional assessments.

IV H Core Capabilities Required for Integrated Ecosystem Assessments

To conduct integrated ecosystem assessments, certain core science capabilities have to be dedicated to each regional unit. These will usually be located in the region itself, but occasionally logistical considerations might justify a more remote site. The important point is that the expertise is focused on the specific regional ecosystem. These core capacities are needed to ensure that within each regional team experts can evaluate the quality and completeness of the data sources used in the assessments and the suitability of the functional relationships assumed. They are also needed to guide the assessments to address the management issues of greatest regional relevance and to detect and respond to changes in the needs of the users of the integrated assessments. These capabilities also provide the knowledgeable and known experts to speak with authority to the diverse clients of ecosystem assessments and NOAA science more generally. Importantly, they have the regional knowledge to know when results of the regional integrated assessments just “don’t make sense” even if the formal diagnostics look normal.

For effective ecosystem science and integrated assessments, core capabilities are needed in three areas:

- Monitoring: The Region has the competence and capacity to collect reliable information using state-of-the-art tools.
- Analysis: The Region has the competence and capacity to apply, adapt, and interpret state-of-the-art analytical methods.
- Integration: The Region has the competence and capacity to analyse and interpret relationships among ecosystem components and between human activities and ecosystem components, and to develop and apply models of those relationships.

Saying that the competence and capacity exists within a Region does not mean that all the expertise has to be housed in NOAA facilities and employed by NOAA. Partnerships with academia, industries, and public interest groups can all play important roles in ensuring that the competence and capacity are available. Nor does the competence and capacity have to be delivered in the same way in every region. However, the partnerships need to be reliable, so the capacity really is available when it is needed. These partnerships cannot give the partners undue influence over the content or interpretation of the results of the integrated ecosystem assessments. For both of those reasons, partnerships comprising important parts of the science capability to perform integrated regional assessments should be sufficiently formally structured that partners are accountable for their contributions to the assessments, and the integrity of the science content is assured.

Whereas collectors and users of data and interpreters of the assessment results require strong regional knowledge to be credible and effective, support tasks such as processing and archiving data and instrument maintenance and deployment do not need to be duplicated in each Region. Many of these service functions have economies and efficiencies of scale that should be exploited. There are also types of specialized expertise best located in a few centers, providing service to the Regional assessment teams as needed (see Text Box). Acknowledging that there is an important role for centers of specialized expertise in providing NOAA with the capability to conduct regional ecosystem assessments does not mean that Regional NOAA researchers cease to do visionary science. The opportunity to strive to scientific excellence should be provided universally to NOAA scientists and their partners in research. Nor does it mean that every region will get what it wants when it wants it. Priority setting across NOAA will remain essential. These centers of specialized expertise just become a key component of the priority

Text Box. The Role of Centers of Specialized Expertise: A number of specialized capacities can be clustered in a few centers of specialized expertise to contribute to regional assessments when and as needed. These are capacities that are not expected to be needed every time an integrated ecosystem assessment is undertaken, or to be routinely engaged in the preparatory work leading up to it or in the interpretational work after it is completed. However, periodically their input to an integrated regional assessment is essential, possibly to integrate new knowledge into the previous assessment framework (e.g,. a breakthrough in climate modelling), to address the implications of an environmental event (e.g., a new invasive species is found expanding in an area), or to consider a possible new human activity in a region (e.g., seismic exploration for hydrocarbons in an area not surveyed in many years).

The centers of specialized expertise must have particular properties. The researchers in these centers should be pushing the boundaries of knowledge and applications with their research. The center scientists must understand that they are accountable for nationally-set priorities, and these priorities should strongly influence the selection of projects by the scientists.   Also the centers have a responsibility to disseminate advances rapidly to Regions, and to participate effectively in regional work according to national priorities. Effective participation will often mean end-to-end engagement in a case-specific application, and not just a visit to an assessment meeting to present a paper on the new developments in the specialised field.

setting and planning.

Many of the core capacities required for Integrated Ecosystem Assessments already exist within NOAA while other capacities need to be strengthened before IEAs can be successfully prepared. In the following sections we described the range of capabilities that must be available at the regional level (IV-H) or in centers of specialized expertise (IV-J).

Conclusion 8: Each Regional ecosystem science enterprise must have an adequate core capacity in sustained observations, analysis of status and trends of ecosystem component, and analysis and modelling of interactions. Increased capability in social sciences focused on ecosystems is also necessary These capabilities do not necessarily have to be housed completely in NOAA facilities, but can be provided in part through partnerships. A number of supporting capabilities can be provided from more centralised centers.

Recommendation 5: Partnerships that are important to the science capability to perform integrated regional assessments should be sufficiently formally structured that partners are accountable for their contributions to the assessments, and the integrity of the science content is assured.

Recommendation 6: The properties of Centers of Specialized Expertise for specialized roles in ecosystem science need to be codified, and a process under direction of the regional ecosystem science coordination group should be created to oversee their establishment and monitor their contributions to regional needs.

IV H 1 Sustained Observations

Much of what we know about magnitude and causes of ecosystem change has been learned from time series observations of the status of ecosystem properties and human activities. They will remain essential because of the complexity of ecosystems and the fact that they face unprecedented perturbations from climate variability and change, habitat change, resource extraction, invasive species, and pollution. Our increasing ability to model and predict variability in the ecosystem will not soon replace the robustness and clarity of interpretation afforded by sustained measurements.

The most numerous ecosystem time series in the U.S. are those collected by NOAA and states as the basis for assessing and managing fisheries and protecting endangered species. Fishery-independent surveys are augmented by monitoring catches in commercial and recreational fisheries. Data on habitat status and trends are also collected as part of coastal-zone and protected-area management. Academic and nongovernmental organizations support scattered ecological time series not necessarily related to management. Data from satellites provides key information on physical and biological oceanographic features. The complexity of this network of observations from different sources and of differing and sometimes changing accuracy and precision means that the resultant data have yet to be integrated into a unified data system.

As management shifts from single species toward an ecosystem approach, sustained observations must expand to better describe inter-species interactions within the ecosystem and those factors that impact ecosystems. Regional NMFS centers have proposed initiatives that would greatly expand the comprehensiveness of NOAA’s 50 years of ecosystem monitoring beyond managed and protected species.

<u>Text Box. Opportunities to expand programs for sustained observations</u>: Because ecosystem behavior is so strongly shaped by the local environment, the nascent Integrated Ocean Observing System (IOOS), which is based on regional groups tending local observing systems, could be an effective mechanism for carrying the NMFS effort to expand ecosystem monitoring into State waters. Unfortunately, recent efforts in IOOS have minimized the need for ecosystem observations in favor of assisting local government agencies and users. The US climate observing systems remain focused on changes in the atmosphere and on oceanic variability that impacts the atmosphere with very little effort placed on the effect of climate variation in the ocean upon marine ecosystems. The NOAA Climate and Ecosystem Program is sub-critically funded. Marine ecosystem management is an important user of climate services that has not been fully recognized.

NMFS and the Coastal Services Center, in particular, have programs that assemble readily available social and economic data on fisheries and other human activities in the coastal zone. These and other programs are producing valuable information products for regional and local managers. However, there is too small, and often an inconsistent, effort directed at producing time series data that can be used by the social science research community to improve our understanding of and ability to explain variations in those human activities that impact habitat, pollute and over exploit the natural resources in coastal and ocean ecosystems.

Climate variations cause physical, dynamical and chemical changes in the ocean, sometimes associated with dramatic changes ("regime shifts") in abundances from plankton to top predators. NOAA recognizes that effective single-species and ecosystem-based management requires accounting for climate forcing. Indeed, NOAA's Strategic Plan lists as a Performance Objective of the Climate Mission Goal to "Understand and predict the consequences of climate variability and change on marine ecosystems." To do so, the US climate observing systems must augment monitoring programs focused on ocean impacts on the atmosphere with ones focused on effects of climate variation in the ocean upon marine ecosystems.

The most rapidly changing impacts on marine ecosystems are from human activities. At the same time, changes in marine ecosystems have direct social, cultural, and economic impacts. NMFS and NOS are both involved in managing the interaction of marine ecosystems and human activities. Both recognize that monitoring changes in human populations and activities is central to this mandate, and they have added several social scientists to their staffs during the last few years. However NOAA programs to implement the US Ocean Commission's recommendation to establish of a national monitoring network for 'understanding of the natural, social, and economic processes that affect oceans and coastal environments' (emphasis added) are only in their early stages. There is a need to strengthen the NOAA social science plan to more comprehensively prescribe what sustained social science observations are needed to meet its ecosystem mandate.

Conclusion 9 Observations of representative indicators of all key elements of the ecosystem should be expanded and sustained. These elements include: managed species and the unmanaged species that interact with them; geological, physical, chemical and biological aspects of habitat; the climate processes affecting habitat and behavior; and economic, demographic, social and policy factors that affect habitat, resource extraction, and the

societal benefits of the ecosystem. Identification of measurements that describe functional parts of, and interactions within, the ecosystem should be incremental and closely connected to analyses and modeling of status and trends.

Recommendation 7: All Line Offices and Goal Teams should be enlisted in planning for an expanded ecosystem monitoring capability. For example, expertise within the Climate Observing System should be exploited to develop improved sustained observations of ocean climate variability that affects ecosystems.

Recommendation 8: NOAA should develop plans to archive, organize, and distribute all the types of data needed to track, forecast and understand change in ecosystems. Starting from now-separate managed-species and climate data, effort should be made to gather and organize existing socio-economic data collected by all sources, observations of unmanaged species and inter-species interactions made by NOAA and others, and all available descriptions of habitat.

Recommendation 9: The NOAA social science plan should specify more comprehensively what social science monitoring data are required for managing human activities that affect or depend on the use of marine ecosystems, and develop a strategy to ensure such data are available.

IV H 2 Analysis of Status and Trends in Space and Time

Extracting information from sustained observations requires analyses to determine the status and trends of the components being observed. For ecosystems, synthesis must include the variations of different species, habitat parameters, environmental and human factors. There is considerable analysis of this type being done today. In areas like exploitable and endangered species and climate variation NOAA takes the lead whereas in other areas, like economic factors or near shore habitat, states and other agencies take significant roles. Most analyses consider only a few factors at a time. The ecosystem approach demands ecosystem analyses in which the variations of all species and all factors affecting an ecosystem are considered together. In what follows we address the mix of analyses that must be included.

Population Dynamics

One of the main responsibilities of the Science Centers within NOAA Fisheries has been to conduct stock assessments of commercially important species. These assessments involve data collection, research, statistical analysis, and forecasts. Over the past 20 years, stock assessment has evolved to use increasingly complex population dynamics models to integrate data sources and biological information. Also population viability analyses (PVAs) are frequently conducted in consultations under the Endangered Species Act to assess the risk of eventual extinction for a particular species.

There is also increasing interest in multi-species and ecosystem models to supplement single species investigations. Multispecies models are simple extensions of single species models, in which species are linked through predator-prey relationships. Mass balance models are more complex, in that all species in the system are included, although often as aggregate functional groups, and the system is “balanced” so that system production equals system consumption. The most complex models are ecosystem models that also may include dynamic physical/chemical and biological relationships and bioeconomic components.

The complexity necessary for integrated modeling and assessment of regional ecosystems and selected subcomponents (e.g., managed species) depends on the societal goals that management and policy are supporting, and the nature of the threats and activities being managed. For abundant populations with few interactions with other species, simple models may suffice. Single species assessments are likely to remain to primary tool for fisheries management for the next 10 years at least, but will be supplemented by multi-species and ecosystem modeling to address key questions that cannot be answered by single-species models.

Habitat

In traditional single-species assessments and more recent multispecies assessments, habitat received little attention, particularly for marine species. For diadromous, estuarine and coastal species, habitat assessments were sometimes important, but usually only in terms of relating changes in a single population to habitat degradation or enhancement projects. In integrated regional ecosystem assessments, habitat dynamics become a central component of the assessments.

To analyse the dynamics of habitat over space and time physical and biological oceanographers, and marine geologists have to interact on an on-going basis, and have regularly updated data on the state of ecosystem components in which they specialize. To place these dynamics in the physical and chemical features of the aquatic habitats in to the context of the integrated assessment, these specialists have to interact routinely with population dynamics experts as well the supporting researchers in fields like marine botany, fish behavior, community ecology, and animal physiology.

<u>Text Box. The role of habitat in integrated assessments</u>: In integrated assessments," habitat" becomes the unifying structure for integrating the bio-physical interactions of the living ecosystem and its environment. Habitat features such as temperature, salinity, water quality, contaminant level, and the other physical and chemical properties of the environment vary both in space and time. Interactions of the physiological tolerances and preferences of the individual populations with the physical and chemical habitat variation represents an initial and direct determinant of survivorship of each life history stage of the population, manifest as variation in the availability of suitable and unsuitable habitat.

Variation in the physical and chemical habitat is also a direct determinant of how the populations distribute themselves in space and over time. The role of habitat in affecting the distribution of populations is increased by responses of organisms to structural habitat features (bathymetric, substrate, etc) and dynamic physical features (currents, tidal regimes, etc). As a major determinant of distribution of populations, habitat has a further role in the bio-physical interactions among populations and their environment, as mechanisms like transport of eggs and larvae and migration of all life history stages can strongly affect survivorship of populations. Habitat also becomes a major determinant of the biological interactions among populations, as the distributions of populations affect encounter rates of predators and prey, and hence their growth and survivorship and locations of spawning aggregations and other social interactions.

Finally many of the first-order effects of human activities on aquatic ecosystems are through changes to habitat features; for example effects of fishing gears and hydrocarbon extraction facilities on the seafloor, introduction of nutrients and contaminants to the water, dredging of navigation channels, etc. Thus, assessments of changes in habitat over time represent a major aspect of evaluating the interactions of human activities with aquatic populations and communities.

To varying degrees all these experts need to reorient their thinking and analytical approaches to have a greater spatial emphasis; perhaps a small change for marine geologists but a much larger one for many population experts. Finally, with human activities comprising a key part of the integrated assessments, the experts on the habitat components need regular interaction with experts working on the levels and spatial patterns of these human activities, so that the assessments can capture the habitat-mediated impacts of the human activities.

These interactions highlight the more important reorientation of thinking in the integrated assessments. The habitat dynamics have to be viewed as the central structure of the assessment, and not just as explanatory variables used to account for anomalies in population dynamics. The habitat dynamics form the foundation for the biological community changes and mediate many of the human interactions with the rest of the ecosystem.

Social and Economic Factors

Applying the ecosystem approach to management of coastal and ocean resources requires an understanding of the fundamental, underlying mechanisms that drive human behavior (Liu

2001), as well as more specific knowledge of how humans use marine ecosystems directly and indirectly for social, cultural, and economic benefits. Some of the more salient factors are demographic (population size and structure), social (perceptions, attitudes, values) economic (markets, production, consumption), and government (laws, regulations, processes). To properly investigate these influencing factors, two major gaps must be closed:

(1) Gaps in time series data on non-market uses and values of ecosystem resources; on social perceptions, attitudes and values; on local laws and regulations that govern the use of land and other coastal ecosystem resources; and

(2) Gaps in research expertise, particularly in the social science areas of demography, sociology and anthropology, political science, and economics – expertise that focuses on attempting to understand the spatial and temporal variations in human activities that affect, and that are affected by ecosystem resources.

Data on market and non-market valuations are critical for supporting broad-based ecological decision making, but existing programs are inadequate to meet the need to understand the social and economic processes that affect oceans and coastal environments. There is a great need to improve the understanding of and ability to explain variations in those human activities that impact habitat, pollute and over exploit the natural resources in coastal and ocean ecosystems. To achieve that end, the social science research community needs time series data that will support investigations of these human activities.

Text Box Current NOAA capacity in social science analysis. NMFS and NOS, particularly the Coastal Services Center, have programs that assemble readily available social and economic data on fisheries and other human activities in the coastal zone. The study by NOAA (1999) represents a good first attempt to document social and economic trends in coastal regions for the period 1970 through 1998. It identifies some of the additional information needs for developing policy based on the best available scientific information. For example, it finds that outdoor recreation and tourism are two of the most important economic activities in coastal areas, and that government plays a critical role in providing the conditions essential to these activities. Although the National Marine Fisheries Service and the Fish and Wildlife Service conduct regular surveys of recreational fishing and hunting, 'much more could be done to understand, document, manage, and promote marine recreation' in coastal areas. There are no time series data on recreational boating and beach use, for example.

NOAA's Coastal Service Center (www.csc.noaa.gov) helps coastal managers apply social science and related tools by providing information on methods for assessing and understanding the social and economic processes that affect coastal and ocean ecosystems. There is, for example, a portal to help managers of marine protected areas use social science tools to accomplish their goals.

Comprehensive economic and social science information is being collected by the National Marine Fisheries Service, consistent with its legislative mandates (See Table II A 1). Non-market valuations are routinely included in policy evaluations of management options under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). The Economic and Social Programs at NMFS account for the vast majority of such research and data collections at NOAA. In addition, the CSC sponsors synthesis of existing economic data sets through a small program: the National Ocean Economics Program at California State University at Monterey Bay (http://noep.csumb.edu). The NOEP provides data on ocean-related economic activities and resource trends for the purpose of assisting government agencies, businesses, and individuals with making investment and management decisions coastal areas. The data include market values of economic activities, and non-market values of both non-consumptive uses and services of coastal and ocean ecosystem resources (NRC 2004). A goal of the program is to understand and estimate the values of non-market assets such as clean coastal waters, estuaries, mangroves, barrier islands, coral reefs, and marine reserves. With these value estimates, managers can appropriately value these resources as they make decisions regarding the use and stewardship of ecosystem resources. These programs rely on data that are currently being produced by others, for instance, the Census Bureau and USGS. They are providing the critical service of assembling and packaging these data into readily available information products.

Conclusion 10 The capabilities to analyze status and trends in populations, habitats, and human activities are all core to NOAA's ecosystem science enterprise. All need to be sustained and expanded at the regional scale, particularly habitat and social sciences, neither have which have been central activities of NOAA science in the past.

Recommendation 10: The core analytical capabilities that NOAA should have for the status of human activities in each region include the following:

- Social science (economics) capacity to analyze the spatial and temporal variations in the uses of the principal ecosystem resources (e.g., land use, extraction of living marine resources, recreation and tourism) in each region;
- Social science (economics) capacity to assess the market and non-market value of human uses of, and the natural services of ecosystems in each region;
- Social science (economics) capacity to assess the benefits and costs of protecting and/or restoring ecosystem resources (e.g., habitat, marine mammals) in each region;
- Social science (sociology and cultural anthropology) capacity to assess the sociocultural values of the uses of ecosystem resources and services in each region.

IV H 3 Integration and Forecasting

Much of the science support for management is needed to forecast the trajectory of ecosystems under different scenarios for management actions, environmental variability, and human actions. Analyses of status and trend are steps toward this kind of outlook but are not forecasts until they projected forward in a model. Models, of course, come in all levels of sophistication ranging from conceptual ones, through empirical statistical techniques, and on to dynamical models based on systems of theoretical or empirical equations, often solved numerically. Here we discuss the integrative studies and forecasts that are needed to implement an ecosystem approach.

Physical-Chemical-Biological Interactions

In the last 50 years environmental forcing of the ecosystems evolve from conjecture to scientific fact. However understanding of the mechanisms by which things like extreme weather, climate variability, pollution, and habitat change impact ecosystems is still far from complete.

Climate variability, particularly regime changes, has significant correlations with abundances and distributions of species on many trophic levels. Indeed the management plans of at least two species incorporate measures of the physical climate. Because climate variability is predictable for many months, its impacts are particularly important for forecasting ecosystem change. As management becomes increasingly accountable for managing essential habitats of species as well the populations themselves, there will be increasing need to model and explore scenarios of how abiotic and biotic components of habitat may change as part of or in response to natural or anthropogenic changes in ocean physical, chemical, and biological features.

Text Box Predictability of the impacts: Conceptually the direct climate impacts are simple. At the lowest trophic level, availability of nutrients affects the primary production that supports the food web, while at all levels factors like temperature affect behavior and competitive advantage. To some degree the effect of such physical factors on single species can be quantified in the laboratory. In the ocean, however, uncertainty about the environment and the interactions within the ecosystem make even direct impacts hard to quantify. Nevertheless, adding nutrients and lower trophic levels to hydrodynamic models has led to some degree of predictability of bulk plankton populations. The significant challenges of transferring this predictability to higher trophic levels are discussed under biological components.

Combining the hydrodynamic models that are used to predict ocean climate variability with biological models presents no conceptual difficulties but there are two fundamental hurdles to be overcome. First, the spatial resolution of ocean climate models must be increased substantially to describe the small-scale processes, like eddies, fronts and upwelling that affect biological communities. Achieving this will require a commitment by climate modellers to address the issues important to marine ecosystems. Second, as biology is added to these models the complexity grows dramatically and the need for empirical information to establish interaction rates grows commensurately. This is a problem to all ecosystem models and some fundamental and very creative research on how to use observations to train these models is required.

The large range of scales and regionally important processes that physical-chemical-biological models must encompass should be dealt with using a two-pronged approach. Centrally, a center of experts in large-scale climate modeling and forecasting, such as GFDL, should expand basin-scale physical-climate models to include chemical factors and the lowest trophic levels. Different local models should be nested within this basin-scale model to describe hundreds of kilometers of coast at higher resolution or focus on specific protected areas, estuaries or other features of localized interest. The basis for such regional and local models already exists in portfolio of the Coastal Services Center and at various academic institutions.

Biological Components

The “raison d’être” of an integrated assessment is to capture the interactions that occur in the regional ecosystems, rather than viewing the dynamics of each population in isolation.

Text Box. Predictability in the relationships: For more than twenty years fisheries assessments have been trying to incorporate at least major predator-prey interactions in assessments, through multi-species assessment approaches. Progress has been sound but slow and highly data demanding. More trophodynamic model-based approaches have sometimes proven less demanding to apply to aquatic ecosystems, but the results have provided only very broad-brush insights into high-level trends, and are inadequate for many of the needs of managers and policy development. These approaches suffer from an inability to resolve the dynamics of individual ecosystem components, too much uncertainty in formulations or parameterisation to guide individual management choices, insensitivity (in the technical sense) to management actions or combinations of those short-comings. Likewise there have been some impressive advances in the integrated assessment of physical-biological interactions in population dynamics contexts, such as GLOBEC and FOCI, but again these have been extremely resource-demanding and will be hard to maintain, let alone replicate in all the regions. Population dynamics experts in areas like fisheries assessments have long expressed a healthy scepticism of the reliability of long-term forecasts, even of the trajectories of individual populations. That scepticism will be even more justified when the forecasts are from complex ecosystem assessments with more poorly known functional relationships and greater uncertainty in many parameters.

Even though the ideal tools for modelling the biological interactions are not yet available, experience has shed light on the capacities needed to further develop such tools and apply them in the integrated assessments. Excellent quantitative skills are a fundamental qualification, combined with expert knowledge of various combinations of oceanography, population dynamics, community ecology and other fields. They need to interact regularly so they have a working familiarity with each others' approaches and concepts. They need regular access to high level analytical tools, because usefully complete models are not going to be simple.

A major function of the integrated assessments will be for exploring scenarios to investigate the sustainability different combinations of human activities in the same area or how different management options may perform under a range of hypotheses about future states of nature. These uses all involve not just assessing the current status and recent trends in the ecosystem components and interactions, but forecasting future trajectories of the ecosystem components and benefits to humans under different hypothesised scenarios. Such forecasts will be highly uncertain, but are essential for supporting sustainable choices for management of human activities in the sea, and for ensuring adequate but not excessive precaution in decision-making and policy. Hence there is a substantial need to increase the capacity for conducting such forecasts and evaluating their robustness. The ecosystem modelling community has been slow to take up some of the advances in forecasting used in other complex areas like research on global climate change and cosmology, such as ensemble forecasting. They have also had relatively little interaction with experts in economic modelling and forecasting. Drawing these types of linkages into the ecosystem assessment capacity in a capacity-building role may allow more rapid progress in improving practice in this crucial area.

Conclusion 11 The provision of integrated ecosystem advice for policy and management requires greatly expanded capacity in forecasting trajectories of ecosystem components under different hypotheses of environmental and anthropogenic forcing. There is evidence that there is some predictability on at least medium-term time scales, but the forecasts will

be highly uncertain, and management and policy need to be informed of the nature and implications of the uncertainties.

IV H 4 Human Activity

Human Uses of Marine Ecosystems

The integration of human activities with the biological, chemical and physical components of marine ecosystems will face many of the same modeling challenges to be faced by experts in population dynamics and oceanography (e.g., in terms of complexity and resolution).

> **Text Box Using bioeconomic models in prediction of relationships:** Advances have been made during the last decade in bioeconomic modeling of fishing activity in which the spatial and temporal variations over time can be reliably forecast over short periods of time. An example of such work is the location choice models applied to fisheries. Holland and Sutinen (1999) modeled the spatial dynamics of fishermen and fish stocks on Georges Bank to investigate the consequences of closing large patches of Georges Bank. This model performs very well in explaining out of sample observations on where vessels operate across seasons of a year. Holland and others have subsequently developed and applied similar location choice models to other fisheries.

To support EAM, such models will need to be nested within larger and more complex ecosystem models, or at least be systematically linked to other component models. For example, bioeconomic models of fishing activity can be linked to models of climate variability to demonstrate how this form of environmental forcing affects human use of fish resources and, in turn, how the fishing community is affected by climate-induced changes in yields from the fishery. Since the feedback does not necessarily stop with the fishing community, the bioeconomic model could be linked to models of land use and other human activities in coastal watersheds – which, when varied, will affect the coastal environment in different ways.

As the ecosystem approach to management is applied to coastal and marine ecosystems, there will be increased demand by managers for spatially- and temporally-dynamic models of human activities that are explicitly linked to the natural components of those ecosystems.

Impacts of Human Activities on the Ecosystem

Knowledge of ecosystem effects of human activities such as fishing and nutrient enrichment of coastal areas is still incomplete, despite significant directed research, and findings are hotly debated among experts. Studies of the ecosystem effects of many other human activities in the sea, such as ecosystem effects of sound due to seismic exploration, shipping and military uses, are still in their early stages. For an ecosystem approach to be implemented in the management of any human activity, knowledge is needed of how that activity changes the ecosystem in which it occurs, the consequences of the changes, and where needed, how to mitigate the effects.

Effectiveness of management measures

Provisions of management plans for specific human activities such as fishing are supposed to keep their impacts on marine ecosystems sustainable, while allowing extraction of social, economic, and cultural benefits to the fullest extent that is sustainable. However, knowledge of the effectiveness of various management measures to mitigate ecosystem effects of human activities is incomplete in all cases, and the effectiveness of many measures has never been tested. The capability to assess the performance of management measures individually, and integrated management plans, is another essential capability for NOAA's ecosystem science.

IV I NOAA Needs Regional Ecosystem Science Coordination Groups for Science

As described above, NOAA, through its various line offices, conducts or supports comprehensive ecosystem science in support of its diverse mandates. Importantly, however, a formal mechanism does not exist to assure that NOAA's ecosystem science conducted at the regional level is coordinated, efficient, or integrated. In order to better serve its clients for integrated ecosystem products, NOAA needs better, more formal mechanisms to coordinate ecosystem science at the regional or LME level. These must overcome the current lack of consistent regional organizational structures among the lines, and the fact that not all Line Offices provide comprehensive national science services.

Text Box. Examples of inter-line office coordination in ecosystem science. In the Alaska LME complex, collaborations primarily between the Pacific Marine Environmental Laboratory (PMEL) and the Alaska Fisheries Science Center have provided the mechanism to coordinate science and to produce IEAs. Similarly, habitat research in the South Atlantic is being coordinated among NOS and NMFS, and additional collaborations exist in other parts of the country, or at the individual project level. NOAA's GLOBEC programs coordinate some aspects of regional ecosystem science as well. However, even these successful inter-LO programs usually focus on a few subjects requiring such interactions, rather than routine collaborations, and most have a finite time horizon.

In order to provide comprehensive and coordinated ecosystem science at the LME level, NOAA has three choices.

<u>Option 1:</u> Adopt a consistent regional management structure among its line offices. For example, NMFS employs a regional structure for its six science centers and management offices, roughly corresponding to the eight LMEs identified by the goal team. However, not all line offices may have the resources to do so or sufficient scientific investment in one or more of the LMEs (regions) to justify such a change.

<u>Option 2:</u> Re-organize NOAA's ecosystem activities into a single line office with a comprehensive regional structure. Although this option provides an organizational structure with clear authority and accountability for regional activities, even if it was implemented, there would still be a need for regional collaborations that extend beyond the ecosystem entity. For example, NWS currently provides critical ecosystem observations from buoys and NESDIS from satellites.

Optimizing ecosystem observations for individual ecosystems would still require such collaborations, and there is the obvious need to collaborate with non-NOAA agencies, academia and other groups.
Option 3: Enable regional integration of NOAA ecosystem science through formation of Regional Ecosystem Science Coordination Groups. These groups, with mandatory representation from all relevant line offices, would be responsible for a variety of tasks related to planning, assessment and the provision of ecosystem-level management advice. Some examples of the duties of these Coordinating Groups would be to develop coordinated ecosystem science plans for each LME, providing a focus for the federal governments "backbone" activities supporting integrated ocean observing systems, production and updating of integrated ecosystem assessments, and coordinating new science initiatives for use in NOAA's PPBES process. Likewise, as regional ecosystem governance institutions become more mature, NOAA's science coordination groups could develop into the science support entity informing these bodies.

Although re-organization of ecosystem activities into a central line office provides the greatest accountability, there are significant costs (monetary, personnel, and institutional) associated with such a major realignment, and such an alignment would not solve all the coordination problems. The eETT does support focused realignment of some programs (Section IV-J), but concludes that a more practical approach for coordinating regional ecosystem science activities appears to be option three (establishment of regional ecosystem science coordination groups). Although not all line offices have regional structures (as noted above), most do have regional resources that are obvious entities for inclusion. For example, while OAR has massed most of its "wet-side" ecosystem sciences in two major centers (PMEL, AOML), it nevertheless has a network of Cooperative Institutes with "wet side" responsibilities. While CIs do not have the same direct accountability as do formal regional structures including SES management, they include a significant amount of the ecosystem science expertise supported by NOAA.

Conclusion 12 The preferred option for providing the necessary coordination of the ecosystem science enterprise at the regional scale is formation of Regional Ecosystem Science Coordination Groups. These groups, with mandatory representation from all relevant line offices, would be responsible for a variety of tasks related to planning, assessment and the provision of ecosystem-level management advice.

Recommendation 11. Accordingly, we recommend that NOAA develop a series of Regional Ecosystem Science Coordinating Groups consistent with the eight national regional LMEs identified by the EGT plus the Antarctic. Each of these regional groups would be chaired by an SES-level manager, and include formal representation by all line offices providing ecosystem sciences in that LME. Duties of these Regional Ecosystem Science Coordination Groups would include planning, coordinating and executing comprehensive plans of marine ecosystem science, and oversight for the production of integrated ecosystem assessments.

IV J Additional Capabilities Needed in NOAA to Deliver Effective Ecosystem Science

Although the eETT finds a number of shortcomings in NOAA capabilities to meet the regional approach recommended above, we also find that substantial capabilities exist on which to build. In this section we turn attention to capacities that we argue do not need to be replicated in each region but could be successfully developed in fewer specialized centers where critical mass could be developed or where the environment – human resources and partnering institutions - would support it.

Conclusion 13 There is justification and opportunity for NOAA and its partners in the ecosystem science enterprise to develop Centers of Specialized Expertise to

1. **build new tools for modeling and forecasting, and new observation instruments**
2. **develop social science capacity for linking with ecosystems governance,**
3. **develop an understanding of society and its response to changing ecosystem components,**
4. **identify changes in ecosystem structure and function,**
5. **perform technical analyses on contaminants and toxicology,**
6. **operationalize biodiversity and invest in taxonomy,**
7. **develop data archiving center and integration capabilities,**
8. **quantify effects of human activities on the ecosystem.**

These kinds of capabilities are needed as part of an ecosystem approach to management. It is critical to develop these capacities and to provide for delivery into each of the regions as appropriate over time.

IV J 1 Building New Tools (Modeling and Forecasting)

Even single-species assessment models are no longer credible when done as "off-the-shelf" cookbook exercises. State of the art assessment methods allow stock-specific experts to take a flexible modelling framework and adapt it to the biological traits and information strengths and weaknesses of the specific stock being assessed. Development of such flexible analytical models was a highly specialized task, done most efficiently by a small and exceptionally skilled team of experts but done by them with an eye to routine use of the resultant assessment modelling tools. The complete tool-box of assessment methods was developed with such an approach, and has served both the broad NOAA fisheries assessment and the wider community of clients of the assessments well.

A similar approach is the only plausible approach for the more complex ecosystem assessment and forecasting tools that will be needed. Every regional center must have the expertise to apply and interpret such models. However development of ecosystem assessment and forecasting tools reliable enough to be credible and flexible enough to be useful will require a set of world-class experts dedicated to the task of tool development. Co-location would be important to speed progress and obtain synergies among different experts. However, these experts would have to have first-hand familiarity with the real-world problems faced in the Regions as each undertakes the ecosystem assessments and scenario forecasting. Moreover, familiarity with a single Region will be inadequate, because every Region will have unique ecosystem features and individual histories of what types of biological information and data available. Using only one Region's ecosystem assessment and forecasting needs as the starting point for the centralized experts in model development risks producing a model well suited to the chosen Region, but insufficiently flexible to receive the necessary wide usage.

During and after model development the experts in the Center of Specialized Expertise will have to have regular interactions with the Regional experts adapting and using the tools, and some presence in the periodic assessment reviews and advisory meetings. Without such regular ground truthing, there is a risk that over time the experts will drift in directions that are either impractical or irrelevant to the actual application of the tools, and the regional experts will fall behind in the adoption of innovations as they are produced. In fact, this need for consistent progress around the country is another argument for development of the modelling and forecasting tools being developed in a centralized facility. Centralisation is needed to ensure that new ideas get a rigorous examination prior to adoption, but get adopted widely just as soon as the tools and their underlying concepts have been tested widely.

Similarly, new instruments to monitor the ocean and components of the ecosystem, as well as to probe specific interactions between species in an ecosystem, will best be developed and tested in Centers of Specialized Expertise, with strong ties to academic and other expertise. New methods are making large-scale in-situ monitoring cost effective and advances in genetic and biological techniques are opening new possibilities for observing marine communities.

Recommendation 12: A co-located team of experts dedicated to development of ecosystem assessment and forecasting tools reliable enough to be credible and flexible enough to be useful should be established and resourced.

Recommendation 13: A co-located team of experts dedicated to development advances instrumentation for marine monitoring should be established and resources. More than one center, with strengths in different technologies, might be appropriate, with all centers closely linked to relevant academic expertise.

IV J 2 Develop Social Sciences Methods for Linking Ecosystem Science to Governance

Governance is a matter of central importance to managing human behavior in an ecosystem context, encouraging certain behavioral patterns and discouraging others.

Text Box. What is governance? Governance is *not* synonymous with management, going beyond it to include the processes by which laws, policies and institutions address societal issues; set the fundamental goals, institutional processes and structures for planning and decision-making; and set the stage within which management occurs. Management, on the other hand, is the process by which resources are organized to achieve specific societal goals within an institutional structure; and organizes the routine work of the agencies charged with achieving the goals.

Governance processes produce government policies and regulations, which are the principal mechanisms for managing human behavior. For example, incentives and regulatory efforts such as zoning and permitting can channel efforts along desired paths and, with their potential for unpleasant consequences in the form of fines or even imprisonment, can discourage undesired behavior. In addition, through education and outreach government may encourage environmental and ecosystem awareness that can encourage behavioral patterns supportive of ecosystem sustainability.

To make an ecosystem approach to management effective, experts must analyze how government policies and regulations are produced, how management services are produced; and ask what conditions lead to government successes and failures. The behavior of individuals and agencies in the public sector can be analyzed by applying the common tools of governance and socioeconomic analysis. These tools help to understand and explain whether the underlying conditions promote government failure or success. The basic idea is that incentives matter – they shape the behavior of resource users and consumers, and they shape the behavior of public officials and organizations too. With such analysis and understanding, it is possible prescribe ways to correct the obstacles in the public sector that lead to failures of government processes and policies. Otherwise, by promoting government intervention without prescribing proper arrangements, we might be encouraging greater inefficiencies, particularly when faced with the complex trade-offs inherence in ecosystem approaches to integrated management.'

Another important issue is how to obtain useful information on public priorities and preferences that can be used in EAM decision making. One component is greater use of opinion polls and general attitude surveys on ecosystem resource issues, designed to require respondents to recognize costs of actions as well as preferences. For this purpose, more structured surveys are needed that specifically ask respondents to make trade-offs, such as stated preference methods, (e.g., contingent choice and contingent valuation)   Another is more labor-intensive ethnographic fieldwork to provide in-depth assessment of values and the degree to which they are strongly or weakly held;

Recommendation 14: NOAA and its partners should develop the social science (political science, public administration, legal) capacity to assess how government (through its laws, regulations, processes) influences the uses of ecosystem resources and services, diagnose sources of governance failure, and identify the necessary and sufficient conditions for producing successful EAM polices.

Recommendation 15: There is a need for NOAA and its partners to develop improved social science (economics, sociology, anthropology) methods for producing information on public priorities and preferences that can be used in EAM decision making.

IV J 3 Develop an Understanding of Society and its Response to Changing Ecosystem Components

Section IV H 2 outlined how an understanding of the fundamental mechanisms that drive human behavior is required for the ecosystem approach to management of coastal and ocean resources. Human populations both affect the status of marine ecosystems and respond to changes in the status of marine ecosystem components. It is well known that the growth of the population and economic activities that occurred at the ocean and Great Lakes coasts during the 20th century was due in large part to economic and quality of life advantages of the associated marine ecosystems (Rappaport and Sachs 2003).[2] Changes in the natural components of these ecosystems will likely induce human responses that have significant consequences for changes in population size and composition, types of economic activities, and distribution of incomes in coastal areas (McGranahan 1999, Marcouiller, Kim and Deller 2004).[3] Other responses, such as in perceptions, values, laws and other institutions, also shape the overall well-being of society and humans attitudes towards the environment.

These human responses tend to occur over large spatial and long temporal scales and, therefore, are best examined by a large, diverse community of scholars. The expertise required for such investigations include demography (population size and structure), sociology (perceptions, attitudes, values) economics (market and nonmarket outcomes), and political science and law (laws, regulations, processes).

Recommendation 16: Centers (physical and/or virtual) of expertise in the spatial dynamics of human responses to ecosystem components should be formed to develop and apply tools for analyzing the large spatial and temporal scales of human responses to changes in the natural components of large marine ecosystems.

IV J 4 Ecosystem Structure and Function

All regional centers would be expected to conduct high-level process-based research on aspects of ecosystem structure and function important to understanding the dynamics of the regional aquatic ecosystems and the impacts of human activities on them. However experts would be needed to give priority to global aspects of these issues, and to integrating the ecosystem-specific advances in regional research centers and internationally into a global synthesis. This global synthesis of regional insights is essential for successful implementation of an ecosystem approach in all NOAA's science activities – research, educational, and advisory.

A center focusing on synthesis of the rapidly expanding knowledge of ecosystem structure and function is essential for several reasons. One is simply that ecosystems are complex, and directly or indirectly, everything is connected to everything else. Nonetheless, for decades the scientific

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[2] Rappaport, J. and J. Sachs. 2003. The United States as a Coastal Nation, *Journal of Economic Growth 8:1-46;* Marcouiller, D., K-K Kim, and S. Deller. 2004. Natural Amenities, Tourism and Income Distribution, *Annual of Tourism Research* 31(4):1031-1050.

[3] McGanahan, D. 1999. Natural Amenities Drive Rural Population Change. Agricultural Economic Report No. AER781. Available at www.ers.usda.gov/Publications/AER781/.

community has argued that certain ecosystem features are particularly essential to maintaining the structure and functional properties of ecosystems. New findings about specific ecosystems need to be viewed in more general contexts and by independent minds, so the features which are considered essential either to specific aquatic ecosystems or to universally get integrated appropriately into the conceptual and operational frameworks in which NOAA scientists and partners are working. Another reason is the sheer rate of growth of publications in this field; scientists with regional research and advisory responsibilities are challenged to fulfill all the tasks expected of them and keep abreast of new developments in even a few selected disciplines. Dedicated experts are needed if NOAA is to stay current with developments.

Yet another reason is that it is essential for NOAA to stay current with developments into determinants and key features of ecosystem structure and function, because one of the frequent criticisms of the “ecosystem approach” is that it is too broad and encompasses so much that the concept is impossible to operationalize. Without question implementing an ecosystem approach as the core of NOAA science’s service to applied clients will be done through triage – selecting specific parts of the ecosystem on which to focus most efforts both in research and in assessment, modelling, and advice, and giving little attention to the other parts. Whenever applied science is selective about what receives focus and what does not, the science is vulnerable to criticism that the choices were wrong. For NOAA’s choices to be credible, they must reflect a full mastery of developments in ecosystem science nationally and internationally.

The Centers of Specialized Expertise in ecosystem structure and function would have a mix of disciplinary experts from ocean physics to biological systems. Their unifying traits would be interdisciplinary thinking and familiarity with the needs of the users of NOAA science. The former would ensure that the groups would focus appropriately on determining those features of ecosystem structure and function that are most important for manage to either protect or respond to. The latter would ensure that the centers did not let interesting theoretical and conceptual challenges take their efforts so far from applications that their insights and discoveries could not be used to improve the support provide by NOAA science to the users of the science.

Recommendation 17: Physical or virtual Centers of Specialized Expertise in ecosystem structure and function must be established and resourced with a mix of disciplinary experts from ocean physics to biological systems. Their unifying traits would be interdisciplinary thinking and familiarity with the needs of the users of NOAA science

IV J 5 Technical Analyses (Contaminants, Toxicology, Etc.)

NOAA maintains a number of specific programs dedicated to assessing toxic contamination in the marine and coastal environment and their effects on biota and implications for humans (see text Box). Toxicology and contamination monitoring programs address non-point source pollution monitoring, seafood safety surveillance, and broader oceans and human health initiatives (See Text Box):

Although these programs address specific issues and circumstances, it is nevertheless appropriate to examine these programs in more detail to determine if there would be synergies and gains in efficiency if re-organized under more central coordination. These programs require access to expensive testing equipment and procedures, and facing tight budgets, NOAA is challenged to maintain state-of-the-art equipment and procedures. Some centralization of analysis capacity is probably warranted, tempered by the need for multiple site-redundant capabilities to assure that if one critical facility is disrupted, the critical functions are maintained. For example, In the case of hurricane Katrina, the National Seafood Inspection Laboratory at Pascagoula was destroyed. In order to maintain critical seafood safety surveillance in the Gulf, the NWFSC in Seattle was able to substitute and provide these functions.

Recommendation 18: Further assessment of toxicology and contamination programs in NOAA should be conducted with respect to their organization and functions to provide for essential services in support of its many trust missions, including the Oceans and Human Health Initiative. The amount of current and required coordination among programs and benefits and costs of reorganization should be the major focus of this review. This review should consider ongoing access to appropriate technologies as well as site redundancy to maintain essential services.

Text Box NOAA Toxicology and Contaminants Expertise:

NMFS: Three Science Centers have ecotoxicology or marine chemistry programs to provide a variety of services, including:

The Northwest Fisheries Science Center (Seattle) program assesses various problems associated with urbanized coastal areas, harmful algal blooms, and monitoring following specific events such as Exxon Valdez and Katrina:
http://www.nwfsc.noaa.gov/research/divisions/ec/index.cfm
http://www.nwfsc.noaa.gov/research/divisions/ec/ecotox/index.cfm

Auke Bay (Alaska) Laboratory of Alaska Fisheries Science Center provides ongoing surveillance for Exxon Valdez and various habitat conservation programs:
http://www.afsc.noaa.gov/abl/OilSpill/oilspill.htm

The Northeast Fisheries Science Center, Highlands NJ Laboratory maintains a marine chemistry program assessing problems of urban contamination, ocean dumping effects and habitat issues
http://www.nefsc.noaa.gov/epd/marchem/

National Seafood Inspection Laboratory (located prior to hurricane Katrina at the Pascagoula Fisheries Laboratory, provides a variety of technical monitoring functions supporting seafood safety
http://www.nmfs.noaa.gov/sfa/sfweb/nsil/index.htm

Aquatic animal health is a program maintained by the Protected Resources Office and focuses on contamination effects related to protected species recovery
http://www.nmfs.noaa.gov/pr/health/

NOS: Multiple NOS programs focus on marine contamination programs related to coastal runoff, habitat quality, general surveillance, and oceans and human health. Additionally, harmful algal blooms and other toxic event sampling are a significant focus of these programs:
http://0-oceanservice.noaa.gov.library.unl.edu/topics/coasts/contaminants/welcome.html

The Center for Coastal Monitoring and Assessment supports the National Status and Trends Program, which includes the Mussel Watch and Benthic Surveillance programs:
http://ccma.nos.noaa.gov/cit/data/ These programs provide long-term monitoring for contamination, as well as additional sampling when specific events occur. It is important to have such baselines in order to measure success of pollution abatement programs.

NOS's Office of Response and Restoration (OR&R) protects the coastal environment from oil spills and hazardous waste sites, and restores damaged natural resources.
http://0-response.restoration.noaa.gov.library.unl.edu/

OAR: OAR's Great Lakes Environmental Research Laboratory (GLERL) supports a variety of programs focused contamination issues both in the Great Lakes, and elsewhere, including Chesapeake Bay:
http://www.glerl.noaa.gov/res/Programs/aqmain.html

Additionally, OAR provides support for air borne sources of contamination through its Air Resources Laboratory

Sea Grant: Individual Sea Grant programs have a focus which includes emphasis on toxicology and contamination programs, for example:
http://www.seagrant.sunysb.edu/HEP/library.htm

Additionally, OAR provides support for air borne sources of contamination through its Air Resources Laboratory:
http://www.arl.noaa.gov/research/programs/airmon.html

Cross NOAA Programs:

A recent large scale initiative related to Oceans and Human Health (OHHI) has brought three line offices together to provide institutional coordination, including NOS (Charleston), OAR (GLERL, Ann Arbor), and NMFS (NWFSC, Seattle):
http://www.ogp.noaa.gov/mpe/ohi/

IV J 6 Biodiversity and Taxonomy

Much of the research associated with supporting an ecosystem approach to management of human activities by NOAA and other regulatory agencies will require considering species that may not be of commercial interest or otherwise familiar to most marine scientists working in the area. Such concerns are central in issues such as detecting and reacting appropriately to the presence of potentially invasive species, but can be important in many other applied areas of ecosystem science as well. Moreover, agreements such as the Convention on Biological Diversity acknowledge an overall commitment to protection of all species, populations, and genomes in an ecosystem, and the demand for accountability for these commitments is growing.

These needs highlight that NOAA ecosystem Science will need access to taxonomic experts in most marine higher taxa, whether for identification of specimens that may be new species to an area or for ensuring reliable inventories of biodiversity in various areas. Likewise, there is a developing field of research techniques and management methods focused specifically on the conservation and protection of biodiversity. NOAA needs access to this expertise, to ensure that the ecosystem science support provided to its many clients is compatible with best practices in biodiversity research and conservation. At least at the present time, neither of these areas is expected to be so dominant in NOAA's business that every regional center needs all this expertise replicated locally. As long as the taxonomic support is available when it is needed, that is expected to be sufficient. Likewise, a few centers working actively on biodiversity science and management questions, and disseminating results rapidly and effectively to regional centers should be adequate for progress in that field to be reflected in the regional work on ecosystem science and support for management and policy. At least to this point, both the scientific concepts and the management approaches to conservation of biodiversity have been straightforward to incorporate into the concepts and approaches already used by ecosystem scientists and managers, so unique sets of practitioners of "biodiversity science and management" would not be needed in each region. However the close integration of the central experts with regional practitioners will be essential to success, but that is no different from the other centers.

Recommendation 19: An inventory of taxonomic experts in NOAA facilities should be established and kept up to date. This is primarily to ensure a common metric for biodiversity.

Recommendation 20: A Working Group of experts including but not limited to NOAA scientists should prepare an inventory of the biodiversity science activities currently on-going in NOAA facilities and by partners. This would include, inter alia, work directly in support of United Nations debates on High Seas Biodiversity under the CBD, bio-prospecting, and invasive species. The Working Group would also be asked for a projection of how demands for such biodiversity science will change over the next 5 years and 20 years.

IV J 7 Data Archiving and Integration

Traditionally, data sets use for a variety of ecological purposes have been locally developed, restricted in content, representing short time series, and archived with a wide variety of data management protocols. Consequently, making these data available in a common format and in spatially disaggregated form that can be used to address more than the purposes for which the data were originally intended has been difficult. NOAA has identified many types of data relevant to ecological systems that are part of its long-term architecture for data. To support complex research on factors influencing ecosystems and for producing integrated ecosystem assessments, consistent data archival and integration protocols must be implemented. In fact, in a number of venues, NOAA and other agencies (e.g., NASA, USGS) are devoting increased attention to the data management and communication activities. For example, much of the activity currently supported by IOOS funds have been to develop and implement more transparent and easy to use standardized data management and archiving for its ecological data.

Two aspects are critical for supporting various recommendations noted above

Recommendation 21: In supporting the regional ecosystem activities for the 8 LMEs, data management and archiving protocols and standardization must be developed in concert among the various NOAA line offices and other entities including the Regional Associations, state and local partners, academic institutions, private corporations and other federal agencies.

Recommendation 22: To produce integrated assessments of all USA marine ecosystems, there must be national compatibility across the regional ecosystems, to allow expertise and advances to be disseminated efficiently.

IV J 8 Ecosystem Impacts of Specific Human Activities

Section H4 discussed the need for increased knowledge of how human activities affect marine ecosystems, and how effective specific management measures are at keeping human uses of marine ecosystems sustainable. Much of the associated research is most logically done in regional centers, integrated with implementation of management plans and monitoring compliance with the plans and the state of the ecosystem in the areas where the activity is occurring. However, the knowledge acquired will have broad implications for other regions, and synergies will be gained by combining the results of different case-specific studies. Thus there would be benefits from methods and approaches developed in Centers of Specialized Expertise and applied in these areas as well. They would consolidate accumulating knowledge, communicate emergent insights, and provide specialized expertise back to regional centers. The latter role would be particularly helpful in highly specialized fields such as the effects of introduced sound on marine organisms, and in assessing effectiveness of technical or economic management instruments.

IV K Provide Incentives for Ecosystem Research with Competitive Grant Program

Ecosystem science is, by definition, multidisciplinary. In the context of NOAA this means that expertise for understanding these complex issues lies in multiple line offices. Collaborations among LOs are therefore necessary to advance science supporting EAM. NOAA is replete with examples where multiple line offices have collaborated on programs of ecosystem science. For example, GLOBEC, the South Florida Everglades program and FOCI are programs providing pioneering ways forward, with practical science products having management significance. In all these cases, explicit funding was added to NOAA's budget to conduct such cross-cutting programs. However, if NOAA is going to transition more of its work to reflect an ecosystem orientation, it cannot rely on long lead time projects that will be few and diverse in order to undertake required work in all the ecosystems in which it seeks to provide advisory science. As noted above, NOAA could re-align its various ecosystem related activities within one science LO with some of the requisite skills. However, since ecosystem science relies on essentially all of NOAA's science (and much provided by other agencies as well), it is not practical to address the integration function alone.

An alternative to re-organization of NOAA to foster integrated ecosystem science is to provide some money to be made available on a competitive grant basis. The grant money could be made available in addition to base budgets to projects investigating important ecosystem science issues, collaboration on data integration, provision of ecosystem level advice, or other similar themes. Some conditions on such money could, for example be, that it would be only for projects involving two or more line offices, is consistent with mission goals, and is granted for a fixed period of time (e.g., is not a permanent re-allocation of NOAA's budget). The objective of such a program is to foster the most innovative, creative and cutting edge research addressing difficult problems. NOAA has some recent examples using competitive programs such as this to elicit such projects. Part of NOAA's 2005 and 2006 allocations for the Integrated Ocean Observing System (IOOS) was made available to NOAA researchers in such a program. In 2006, NOAA line offices offered 70 proposals for about $3.6 million in funding to advance the IOOS theme. One would expect that at a similar level (e.g., $4 to $10 million annually) that NOAA's ecosystem scientists could be similarly engaged. In order to run such a competition, NOAA could use one of its Councils or Committees (e.g. Research Council, NOAA Ocean Council, or the Ecosystem Goal Team). The council running such a process would be responsible for establishing annual criteria, and developing a selection process. Such an internal program would foster internal excellence and provide positive incentives for the collaborative "one NOAA" science necessary for NOAA to achieve its ecosystem vision.

Recommendation 23: Establish a competitive grants program designed to encourage cutting-edge collaboration on ecosystem science among NOAA scientists in different LOs.

IV L Enhancing the Role of EGT and PPBES to Support an Ecosystem Approach to Management

Among the most important tools an agency has to effect policy decisions is the planning and allocation of budget in support of management. In section IV E we noted that throughout NOAA and its partners there is the intent to place management and regulatory roles on an ecosystem basis. Line Organizations are reorganizing their roles in the NOAA science enterprise to provide a stronger ecosystem basis for policy and management. NOAA correspondingly acknowledged the central role of ecosystem approaches through the prominence of the Ecosystem Goal Team (EGT), whose purpose is to coordinate ecosystem science planning across LOs. The EGT operates largely through the Planning, Programming, Budgeting, and Execution System (PPBES), providing a matrix structure for linking the theme (Ecosystems) to the agents (LOs). Conceptually, matrix planning in a complex organization with multiple mandates may be the only way to minimize redundancies and maximize synergies of programs on a common theme whose funding is delivered to different LOs. However, the PPBES system is necessarily a high-level and central coordinating body, working at a national scale and up to several budget cycles ahead. Moreover, the EGT/PPBES planning is national but there are significant regional coordination needs for ecosystem science for management activities across LOs and with external partners.

Several concerns were raised with the eETT in its interviews and based on the collective experience of its members. First, the compressed time frame for the PPBES process may be an impediment to allowing the EGT to be as effective as desired at inventorying all that is planned for ecosystem science in each program and regional center of each LO each year, let alone coordinating all those activities through planning and budgeting. Second, some of scientific planning issues like assignment of ship time may be longer term than the current planning commitments required in the planning and budgeting system. This may force commitments ahead of the ability to assure funding, project personnel, etc. using the present approach. Third, transitioning from NOAA's traditional line office organization and from its many single sectoral mandate orientations must be seen a process not an end in itself. It is a process that can take place more or less rapidly to the extent leadership is consistent, that the agency personnel endorse the direction and process of change and to the extent that the external environment is supportive of the direction and process of change.

The implementation of NOAA's matrix and PPBES has provided considerably more formal coordination and transparency in budgeting decision-making. The preponderance of sentiment in responses to eETT inquiry is resignation and cautious optimism, but little enthusiasm. It is not clear that the eETT can make a compelling case for or against the PPBES approach; however, there appear to be two legitimate and difficult issues. First, a fair number of respondents had problems not with the need to plan and coordinate with other program managers but with PPBES as the mechanism to accomplish that end. In general the issue was with the compressed timeframe required by the formal process.

To that end, the eETT would recommends the following:

It appears that the PPBES process is gaining traction as a mechanism within NOAA to achieve desired results. Most agree that the learning curve is steep for how to use the process most effectively. Thus, the PPBES process is in an adaptive mode and changes are being made to adjust to realities. The key here is for NOAA and its EGT to devise ways to get on with the task of expanding and integrating ecosystem assessments into NOAA's management approach at the regional level. These concerns seem to be well-appreciated by the PPBES leadership

Recommendation 24: The PPBES process, supported by the EGT, should continue to reconsider what timelines for both annual and multi-year planning best facilitate coordination among NOAA entities and their partners for ecosystem science and research, and adapt as needed to apply them. In addition, review of the sequencing of the timeframes for planning and coordinating of scientific research across LOs

PART V RESPONSE TO NOAA'S STATEMENT OF TASK FOR THE EETT

The eETT has had to undertake a fairly general assessment of NOAA's ecosystem science enterprise, given the complexity of the question of what comprises "ecosystem science in support of management and policy", the size and diversity of NOAA and its partners, and the many changes ongoing in the NOAA ecosystem science enterprise. Our recommendations provide direction for guiding change, even though we cannot produce a program-by-program, line office-by-line office or location-by-location response to the questions posed. The eETT anticipates that by providing independent perspectives on agency processes, NOAA can act through its existing EGT or ad hoc bodies where detailed assessments are required. Like the RRT report that initiated this review, the eETT recommends that NOAA SAB in conjunction with the NEC review implementation progress after two years to evaluate NOAA's responses to the our recommendations.

Transitioning from NOAA's traditional line office organization and from its many single sectoral mandate orientations must be seen a process not an end in itself. It is a process that can take place more or less rapidly to the extent leadership is consistent, that the agency personnel endorse the direction and process of change and to the extent that the external environment is supportive of the direction and process of change.

NOAA asked two multipart questions, "Is the mix of science activities conducted or sponsored by NOAA appropriate to its mission needs including legislative and regulatory requirements/" and "How should NOAA organize it ecosystem research and science enterprise?" We respond to the questions in the order they were presented to us. To avoid inconsistencies there are intentional redundancies between this section and earlier ones. The responses in Part V are linked directly to specific sections of Part IV where readers may find support discussion for our answers.

V A Is the mix of scientific activities conducted and/or sponsored by NOAA appropriate for its mission needs, including its legislative and regulatory requirements?

The short answer to this question is that the mix of activities is not optimal. There is a significant demand for more activity in many areas. Deficits are particularly great in integrating current products that serve narrow purposes (Section III) and in addressing the human component of aquatic ecosystems (Sections IV H 1 and J 2-3). We stress that the current products are of high scientific merit and do serve important uses, such that there would be significant costs to terminate most existing programs. Moreover, by NOAA's own accounting there are very few of its Ecosystem Goal areas where current funding is at 100% of necessary capacity to meet existing mandates, and an integrative ecosystem science enterprise must address more than the sum of work addressing existing mandates. Three changes are needed:

1. There are opportunities to organize activities to be more effective and reflective of changed priorities, building on the work of the EGT. These are discussed below, and in Section IV-D, H, and J.
2. Clients of NOAA science products and advice must be encouraged to coordinate and integrate their demands for support. This is consistent with the concepts of both the

ecosystem approach and integrated management, which lie at the root of the call for a review of the NOAA ecosystem science enterprise. This is discussed in Section III.
3. As both the US COP and Pew Ocean Commission noted additional resources will be needed for NOAA to deliver effective ecosystem science in support of management and policy. Progress on the recommendations of the eETT will be subject to availability of resources to support or provide incentives for change.

In general even today more high quality science is available than currently is used in making management decisions. This gap highlights the need to continually work on effective provision of scientific decision support services, communication of science, and ensuring ways to obtain feedback on the scientific questions that managers and society want answered. It is also important to educate or train managers on how to use ecosystem information.

With regard to subject matter, within each region NOAA has developed core capacities in the foundations of integrated ecosystem assessments: monitoring and assessing status and trends, and integrating relationships and forecasting trends (IV H 1-4). These must be maintained and enhanced, to support Integrated Ecosystems Assessments. Beyond the integrated ecosystem assessments linking climate forcing and effects on biological communities and their implications for society appear to be a key element. Forcing through anthropogenic effects like pollution, harvest management, harmful algal bloom forecasting, etc. is extremely relevant (III). With respect to specific capacities, NOAA needs to consider how to strengthen analytical capacities in the form of new tools for modeling and forecasting, social science methods for linking ecosystem science to governance and for identifying how humans respond to changing ecosystem components, ecosystem structure and function, technical analysis of toxics and contaminants and their ecosystem roles, biodiversity and taxonomy to support an ecosystem approach, data archiving and integration and ecosystem impacts of human activities (IV J 1-8).

Distribution along the continuum from long term research to products for immediate use?

The nature of ecosystem science seems to the eETT to differ somewhat from NOAA's physical science advice responsibilities. Ecosystem responses to physical or anthropogenic forcing are often non-linear. Changes in forcers can produce subtle but important biological response, often with poorly understood thresholds for more dramatic responses to incremental changes. These effects require monitoring of physical, biological, and anthropogenic features at multiple scales. Hence essentially all ecosystem science will be designed for medium to long term research, but will be producing applied results for the lifespan of the project.

Internal and external (to NOAA) balance?

The eETT cannot answer to this question. Responses to the eETT from the academic community were predictably that its members would like to see more external funding for ecosystem science and concern was expressed by this community over loss of continuity during uncertain fiscal situations. Clearly NOAA has benefited by having the resources to sponsor external science and research though contracts, Cooperative Institutes, etc. As best we can ascertain, the choice to develop internal versus external arrangements for ecosystem research has not been systematic and it is difficult for us to advance a set of definitive guidelines that would serve NOAA better than to take advantage of the circumstances as they present themselves. We recommend regional coordination of the ecosystem science enterprise (IV-D) and the optimal balance might be best set at these scales. We do recommend that where NOAA is dependent on external institutions for meeting core capacities for monitoring, trends assessment and forecasting, these relationships should be formalized (IV H).

Links to international science programs?

Most of the developed world is moving in the same direction, and in some areas where NOAA is constrained by litigation and legislative mandates, other jurisdictions may have made more progress. As NOAA integrates around a science for ecosystem approach to management, there may be opportunities to make stronger connections between the different international scientific bodies in ways to better integrate the science, rationalize the observing systems, improve data sharing and archiving protocols, etc. It is also important to NOAA consider ways to collaborate with other agencies to assist developing countries, in particular, with developing scientific and management capacity and scientific literacy.

V B How should NOAA organize its ecosystem research and science enterprise?

The eETT recommends that the eight regions as defined by NOAA's LME regions within the US jurisdictions and the Antarctic become the focal points for organizing and locating scientific core capacities (IV-D, IV-E). A regional organization maps fairly well on the current location of NOAA's assets to provide core capacity for scientific decision support services in these regions (IV H). Within each region and at the national level, the eETT recommends that NOAA develop a much stronger collaborative approach to ecosystem science. Within NOAA itself the Ecosystem Goal Team and other coordinating mechanisms are working. However at the regional level, the eETT recommends that NOAA needs to work with other local, state and regional interests and agencies to develop a coordinate ecosystem research plan (IV D), that NOAA develop regional coordination across line offices and with research and management partners in order to utilize respective authorities, expertise and assets more effectively in understanding and managing the region (IV E). The starting point for this regional coordination is recommended to be the development of an Integrated Ecosystem Assessment for the region that is responsive to various science and management needs (IV F). There are a number of areas of specialized expertise that are best centralized, with clear mandates and mechanisms to ensure that they support the regional teams when and as needed (IV-J).

This regional focus is also an indication that the eETT believes that there are significant benefits to regional flexibility in addressing local needs that are determined by the interactions between society and watersheds, coastal and offshore environments. Although it is impractical to manage the entire ecosystem science enterprise centrally, the EGT should have sufficient authority to ensure the coherence needed in the implementation of national policies.

The relationship to non-ecosystem science activities (e.g., weather, climate or mapping)?

The eETT agrees with NOAA that branding weather and climate as non-ecosystem components is an artificial separation. Both weather and climate are key forcing elements in biological and anthropogenic systems, making these activities crucial for the Ecosystem Goal at present. Cooperation and collaboration in scientific research will accentuate their roles in the future. The rationale for administrative separation of Climate Goal and Weather and Water Goal from the Ecosystem Goal is less important than ensuring productive cross Goal working relationships. and better understanding of the influences is critical.

Conventional mapping of the sea floor for navigation and security purposes will gain an additional function as ecosystem assessments and ecosystem approaches to management hare inherently spatial (IV-G). An expert internal Working Group or other cross line office and cross goal mechanism may be needed to explore how to achieve new synergies in technologies, data gathering and archiving capabilities, etc. coupled with the need to provide mapping and data products for multiple users at different scales (IV-G, IV J 7).

The continuum from long term research to information products for immediate use (including mandated scientific advice)?

At the level of detail the eETT has been able to muster, we have suggested that there are certain core capacities that need to exist at the regional level (IV H) and we have recommended that NOAA examine how actual or virtual groups could be established to advance development of methods and techniques in some specific areas (IV J). Although PSTT recommended that short term research, i.e., less than five years to fruition, be located in NOS whereas longer term research would be done through OAR, the eETT did not see value in a similar division in ecosystem science and research. Rather we found that most ecosystem science is a gradual and cumulative process that nonetheless yields information and advice on management and policy on a seasonal or annual basis. Thus, for the eETT a "time to fruition" approach was not compelling as a criterion for location of ecosystem research.

Line office distribution?

Line office distribution with respect to the Ecosystem Goal has been dictated largely by legislative mandates. Absent a move by Congress to amend these mandates and require a restructuring such as recommended by the US COP and the Pew Commission, the eETT does not propose radical administrative reorganization. Rather, the eETT sees that over the next three to five years, mandated activities will necessarily expand in the ecosystem scope of their approach simply to improve management and policy, and to better comply with NEPA. Already, there is a demonstrated expansion of management concerns across line offices, federal, state and local partners (Appendix 4). However, without effective integration by empowered coordinators this expansion will create both gaps and redundancies, neither of which NOAA or its clients can afford (III C, IV-D). **We assume that the form of institutions will follow function, i.e., in 5-10 years the organizational changes required to better implement and ecosystem approach will be more apparent and can be legislated or made administratively. The key here is for NOAA and its EGT to devise ways to get on with the task of expanding and integrating ecosystem assessments into NOAA's management approach at the regional level.**

Program structure used in NOAA's Planning Programming Budgeting and Execution System?

The implementation of NOAA's matrix and PPBES has provided considerably more formal coordination and transparency in budgeting decision-making. The preponderance of sentiment in responses to eETT inquiry were resignation and cautious optimism, but little enthusiasm. It is not clear that the eETT can make a compelling case for or against the approach; however, there appear to be two legitimate and difficult issues with some salience. First, a fair number of respondents had problems not with the need to plan and coordinate with other program managers, but that the compressed time frame for the PPBES process was an impediment to performing those activities as part of the process. The second issue concerns long term planning commitments, like assignment of ship time and how the PPBES process may force commitments ahead of the ability to assure funding, project personnel, etc. In this regard, the eETT recommends that the PPBES process consider what timelines for both annual and multi-year planning best facilitate coordination among NOAA entities and their partners, and adapt as needed to apply them.

Other categorization schemes, such as by scientific discipline, mission area or mandate (implicitly including all sectors that are users of science advice), ecosystem or region, internal/external, etc.

This catch-all element at the end of a long list of requests for eETT comment on NOAA ecosystem science and research is one that the eETT did not specifically address at the present time. As we reviewed the Preliminary Report we realized that there were many connections that could be made but we did not succeed in accomplishing that task. Among these elements would be things like how to organize NOAA's Geographic Information System (GIS) technical support; where other gains in efficiency could be realized, etc.

At this point, for the valiant reader who has stayed with the text so far, we request your comment and advice on how well we have responded to the Statement of Task for the eETT and we ask your suggestions on how to organize NOAA to accomplish more under present and foreseeable circumstances.

GLOSSARY

BMP:	Best Management Practice
CBD	Convention on Biological Diversity
CI	Cooperative Institute
CFM	Coastal Flooding Model
eETT	External Ecosystem Task Team
HAB	Harmful Algal Bloom
IEA	Integrated Ecosystem Assessment
iETT	Internal Ecosystem Task Team
IOOS	Integrated Ocean Observing System
LO	Line Office
MMA	Marine Managed Area
MOU	Memorandum of Understanding
MPA	Marine Protected Area
NaNOOS	Northwest Association of Networked Ocean Observing Systems
NCCOS	National Centers for Coastal Ocean Science
NMFS	National Marine Fisheries Service [NOAA Fisheries]
NMSP	National Marine Sanctuary (Program)
NOS	National Ocean Service
NOAA	National Oceanic and Atmospheric Administration
OAR	Ocean and Atmosphere Research
PacOOS	Pacific Ocean Observing System
PVA	Population Viability Analysis
RRT	Research Review Team
SAB	Science Advisory Board

APPENDICES

APPENDIX 1 EETT/IETT MEMBERS AND LIST OF PERSONS CONTACTED AND MEETINGS ATTENDED

A. List of eETT and iETT Members

eETT Members	*iETT Members*
Dave Fluharty - chair	Steve Murawski - chair
Jake Rice - rapporteur	Peter Ortner – vice chair
Mark Abbott	Gary Matlock - NOS
Mike Donahue	Kristen Koch, - OAR
Russ Davis	Mark Holliday - NMFS
Stephanie Madsen	Mel Gelman - NWS
Jon Sutinen	Mike Ford – PPI
Terry Quinn	Erik Cornellier – PA&E

Staff: Kirsten Larsen, NMFS.
Laura Bozzi, SAB [Knauss Fellow]

B. List of Contacts

The eETT members appreciate the time that NOAA people and others gave us as we tried to take the pulse of a very large agency. Due to time and schedule constraints it was not possible to perform a systematic set of site visits nor were we able to sample all programs in NOAA. Anyone who reviews the list below will discover that it is an eclectic mix of people we identify. Still it is consistent with the request of NOAA to sample its vast enterprise, consult with partners and to explore external perspectives at the international level and the academic and stakeholder level. Many more contacts were made than reported here but mostly on an informal basis. We plan to continue to make contact with people to obtain comment and insights based on this Preliminary Report and as we move toward the final report.

A contact as defined for this list is a meeting or telephone conversation specific to the task of the eETT between one or more respondents and one or more Task Team members. These contacts ranged from as little as 15 minutes to several hours. Most were based on a formal set of questions but informal interactions around these themes also yielded important information.

In addition to the individual contacts, eETT members attended a number of professional meetings and were invited to attend meetings of various NOAA components. It was invaluable to see how NOAA presents itself at professional meetings and to observe how the nitty-gritty of agency planning actually takes place. At some of these meetings it was possible to make presentations of the work of the eETT. Work in progress is not as interesting as final results in terms of catching public sentiment. Further, there is not a lot of excitement generated by reviewing organization charts among the public, however, there is a lot of excitement among those whose careers are built by knowing how an agency is organized and who care deeply about better ways to meet NOAA's multiple ecosystem science responsibilities.

The list is organized alphabetically for lack of another rationale. We identify the NOAA Line Office and program wherever possible but not necessarily the title of the position. This is because we want to emphasize that input from the bench-level scientist as well as the boss is needed for development of our perspective. Any titles used are those at the time of the contact in recognition that a number of the contacts have moved to other positions over the course of this review. In this regard, we want to thank again the iETT members and the NOAA authors and reviewers of the White Papers (Appendix 3). We apologize in advance to anyone who may have participated in a meeting or on a conference call whose contribution is not noted below. Please help us correct any gaps.

Susan Abbott-Jamieson, NMFS, Fisheries Statistics and Economics Division
Tundi Agardy, Sound Seas, Washington, DC
Jackie Alder, University of British Columbia, Sea Around Us Project, Vancouver, CAN
Michael Belaev, PICES, National Marine Resources Committee, Moscow, Russia
Heather Brandon, Ocean Policy Coordinator, Office of the Governor, Alaska
Douglas Brown, NOS, Coasts and Marine Resources Program
Leon Cammen, OAR
Marie Colton, NOS, Technical Director
Ned Cyr, NOAA Climate/Fisheries
Penny Dalton, previously CORE, Washington Sea Grant
Douglas DeMaster, NMFS, Alaska Fishery Science Center
William J. Douros, NOS, Monterey Bay National Marine Sanctuary
Michael J. Dowgiallo, NOS, NCCOS
Louie Echols, Washington Sea Grant
Beth Fulton, CSIRO Marine Research, Australia
Michael H. Fulton, NOS, Center for Coastal Environmental Health and Biomolecular Research
Marc Hershman, US Commission on Ocean Policy, School of Marine Affairs, University of Washington
Molly Ivens, AOOS
Steve Gittings, NOS, Marine Sanctuaries Division
Mary Glackin, Assistant Administrator for Program Planning and Integration at NOAA
Alf Håkon Hoel, University of Tromsø, Norway
David Jansen, House Resources Committee, Fisheries and Oceans Subcommittee
David Johnson, NOS, Center for Coastal Fisheries Habitat Research
James Kendall, DOI, Minerals Management Service
Gene Kim, Knauss Fellow, House Resources Committee
Suam Kim, PICES, Pukyang National University, Pusan, Korea

Chester J. Koblinsky, OAR, Climate Program
Ants Leetma, OAR, GFDL
Sandy MacDonald, OAR Executive
Robert E. Magnien, Director, Center for Sponsored Coastal Ocean Research
James Mahoney, Assistant Secretary of Commerce for Oceans and Atmosphere and NOAA Deputy Administrator
Garry Mayer, NMFS, Habitat Conservation Program [NOS, Coral Advisory Bd.]
Ana Parma, Centro Nacional Patagonico, Argentina
Clarence Pautzke, North Pacific Research Board
Robert Pavia, NOS, Special Assignment, West Coast Ecosystems
R. Ian Perry, PICES Secretariat
Richard Rosen, Assistant Administrator for Oceanic and Atmospheric Research and Chair NOAA Research Council
Mary Ruckelshaus, NMFS, Northwest Fishery Science Center
Paul Sandifer, US Commission on Ocean Policy
Edward Sarachik, University of Washington, JISAO, Seattle
Kitty Simonds, Executive Director, Western Pacific Fishery Management Council
Richard Spinrad, OAR Executive
John Stein, NMFS, Northwest Fishery Science Center
Kevin Stokes, Chief Scientist, Seafood Industry Council, New Zealand
Ole Tougaard, Fisheries Directorate, European Union, Brussels
Usha Varanasi, NMFS, Director, Northwest Fishery Science Center
Charles Wahle, NOS, MPA Science Center
David Whaley, House Resources Committee, Fisheries and Oceans Subcommittee
David Witherell, Deputy Director, North Pacific Fishery Management Council
Emily Woglom, Office of Management and Budget
Warren Wooster, Professor Emeritus, School of Marine Affairs, University of Washington
Ruth Yender, NOS
Konstantin Zgurovsky, WWF Far Eastern Branch, Vladivostok
Chang Ik Zhang, Presidential Commission on Policy Planning, Korea

C. List of Meetings

Coastal Zone 05, New Orleans 2005
American Fisheries Society, Anchorage, 2005
NPFMC Ecosystem Committee, Scientific and Statistical Committee
NAS Ocean Studies Board Meeting, Woods Hole, 2005
NMFS Science Board, Pacific Grove 2005
NMFS Fishery Science Laboratory Deputy Directors, Seattle 2005
PICES Vladivostok 2005
NMSP/NCCOS Meeting, Monterey 2005
NOAA Science Advisory Board, June, August, November 2005
NOAA SAB Research Review Team 2005

APPENDIX 2 EXTERNAL ECOSYTSTEM TASK TEAM: TERMS OF REFERENCE

FRAMEWORK FOR AN EXTERNAL REVIEW OF

NOAA's ECOSYSTEM RESEARCH AND SCIENCE ENTERPRISE

Prepared by the NOAA Internal Ecosystem Research and Science Task Team[4]

Background:

The NOAA Research Review Team (RRT), under the auspices of the NOAA Science Advisory Board, conducted a "Review of the Organization and Management of Research in NOAA." The team's report, along with the SAB transmittal letter accompanying the report, is posted at http://www.sab.noaa.gov/Reports/Reports.html.

The RRT report questions where ecosystem research activity is located in NOAA. It contains the following recommendation:

> *"…NOAA should establish an external Task Team to evaluate and strengthen the structure and function of ecosystem research in, and sponsored by, NMFS, NOS and OAR."*

Extracts from NOAA Research Review Team's report relevant to the location of ecosystem research are given in Annex I (from pages 16-18 of the Report).

NOAA agrees with the recommendation of the RRT for an external review on ecosystems. NOAA has decided that the review should be broad enough to address the entire ecosystem research and science enterprise[5].

NOAA conducts mission oriented research and scientific activities on a diverse range of topics, on time scales ranging from decadal scale studies of system processes to short term studies for immediate application. NOAA's entire ecosystems research and science enterprise includes:

- Scientific advice and information products tailored to user needs,
- Observational systems to assess and characterize changes in ecosystems and ecosystem uses,

[4]The NOAA Internal Ecosystem Research and Science Task Team was established by the NOAA Research Council. Its members are Michael Sissenwine (chair), Peter Ortner, Jean Snider, Sennen Salapare, John Janowiak (Melvyn Gelman, alternate), and Michael Ford.

[5] The NOAA ecosystem research and science enterprise is the set of NOAA supported activities (internal and external) that adds to the body of scientific knowledge and translates it into products and services that support the Agency's mission.

- Applied research (not tied to immediate user needs) to better understand processes in order to improve the capability of observing systems and the quality of information products (including scientific advice),
- Development based on results of applied research, of new science tools, conservation technologies, and production technologies.

Annex II elaborates on these categories of scientific activity.

The NOAA ecosystem research and science enterprise needs to support the NOAA Strategic Plan (http://www.spo.noaa.gov/pdfs/NOAA%20Strategic%20Plan.pdf), which is based on stakeholder input and internal assessments of NOAA's mandates and mission. The Strategic Plan has four mission goals including an Ecosystem Goal to "Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach." To fulfill the Strategic Plan, NOAA adopted a Planning, Programming, Budgeting, and Execution System (PPBES, https://www.ppbs.noaa.gov/about.html). NOAA organized its activities into forty four Programs (https://www.ppbs.noaa.gov/PDFs/program_manager_list.pdf), including nine Programs that address the Ecosystem Goal (1) ecosystem research, (2) ecosystem observation, (3) protected species, (4) fisheries management, (5) aquaculture, (6) coastal and marine resources, (7) habitat, (8) corals, and (9) enforcement. Some of the Programs are managed by a single NOAA Line Office (for the LO structure see http://www.noaa.gov/pdf/noaa-org-chart030804.pdf), while others are "matrix managed" across LOs. Most of the NOAA's Ecosystem Research and Science Enterprise is within the Ecosystem Goal. However, the Ecosystem Goal benefits from scientific activities of other Strategic Plan Goals, which, for example, provide environmental information that, can be used to help predict ecosystem changes.

What is an ecosystem? For NOAA's purposes, an ecosystem is defined as a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.

What is an ecosystem approach to management? For NOAA's purposes, and ecosystem approach to management is management that is adaptive, specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives.

This document offers a framework for conducting the external review. It suggests:

- Terms of Reference,
- Size of the review team and reviewer qualifications,
- A method for selecting review team members,
- An approach for conducting the review.

Terms of Reference

The purpose of the review is to answer the following questions:

Is the mix of scientific activities conducted and/or sponsored by NOAA appropriate for its mission needs, including its legislative and regulatory requirements, in terms of

- Subject matter,
- Distribution along the continuum from long term research to products for immediate use (including mandated scientific advice),
- Internal and external (to NOAA) balance?
- Links to international science programs?

How should NOAA organize its ecosystem research and science enterprise, in terms of:

- The relationship to non-ecosystem science activities (e.g., weather, climate or mapping), which is in part an artificial separation,
- The continuum from long term research to information products for immediate use (including mandated scientific advice),
- Line Office distribution,
- Program Structure used in NOAA's Planning, Programming, Budgeting, and Execution System,
- Other categorization schemes, such as by scientific discipline, mission area or mandate (implicitly including all sectors that are users of science advice), ecosystem or region, internal/external, etc.

In answering these questions, the review should include the following:

- Strengths and weaknesses of existing organizational structures used by NOAA, and by other entities with missions similar to NOAA's (domestic, foreign and multinational).

- Advantages and disadvantages of requiring that all scientific activity within a category of research, (e.g., long term or short term) be organized in the same way.

- How well organizational structures and approaches facilitate the transition from research to operations and information .products,

- How well organizational structures and approaches facilitate the transition from research to operations and information products.

- How well organizational structures and approaches enhance the relevance, responsiveness, quality and credibility of scientific advice and products.

- Cost implications of organizational structures, including the transition costs of change,

- Ecosystem related implications of the report of the report of the US Commission on Ocean Policy and the President's Ocean Action Plan.

- Ecosystem implications of international agencies of which the US is a member (groups including but not limited to regional fisheries management organizations, such as ICES, PICES, CITES, and various UN agencies such as FAO and UNESCO).

I. Size of the review team and reviewer qualifications

NOAA's ecosystem research and science enterprise is large and diverse. Thus it requires a relatively large review team to do justice to the Terms of Reference. The review team should have at least seven members with a variety of backgrounds (recognizing that even with seven reviewers, it will not be practical to have all backgrounds represented), such as:

1. Scientific disciplines of physical sciences, biological sciences including fisheries science, and social sciences,

2. Experience in academia, within mission oriented government agencies, Non-Governmental Organizations (NGOs), and the private sector,

3. Familiarity with NOAA's mandates,

4. Being a science provider to key generic groups of stakeholders, science interpreter to groups of stakeholders, science user, or .stakeholder with a history of interaction with science providers.

The reviewers should have the following qualifications:

1. National and international professional recognition,

2. Knowledge of the scientific information needs to support NOAA's ecosystem stewardship missions, coupled with broad familiarity with NOAA's total mission,

3. Knowledge of, and experience with, the organization and management of complex mission oriented scientific programs,

4. No perceived or actual vested interest or conflict of interest that might undermine the credibility of the review.

It is of note here that except for qualification criteria 4, the criteria are not absolute requirements. The qualifications of some individuals are expected to be outstanding enough with respect to one or more of the criteria, that being unqualified with respect to other criteria, would not necessarily make them ineligible. Because of the limited size of the review panel, management organization expertise must include expertise on ecosystem science or the very special features of science applied to government decision-making.

II. A method for selecting review team members

Nominations should be submitted to the NOAA Science Advisory Board (SAB) with justifications that address the candidate's background and qualifications (specifically for the categories above). The nominations should indicate if the candidate has expressed a willingness to serve, if selected.

The results of the review have the potential of being controversial because the results of the review (if implemented) may have direct consequences on social and economic opportunities and/or quality of life of some of NOAA's stakeholders. This is a key reason for providing stakeholders the opportunity to nominate review team members. Moreover, it is important that stakeholders have the opportunity to provide input to the review team, and that the process of selecting reviewers be transparent. Accordingly, nominations will be solicited by a notice in the Federal Register, which summarizes the information in this document. Anyone (from within or outside NOAA) should be eligible to nominate. Individuals may self nominate. However, employees of NOAA or persons currently funded by NOAA should be ineligible to serve as a review team member.

It will be up to the SAB to evaluate the nominees and select the review team members. The intent is to select from the nominees. However, the SAB should retain the prerogative to name people to the review team that were not nominated if it deems it necessary to achieve the desired

III. The SAB will post the review panel, with abridged resumes, for public information, to close the loop on transparency and develop an approach for conducting the review.

IV. Review Approach

There are several aspects of the review approach that need to be specified, including:

1. Role of the NOAA Internal Ecosystem Research and Science Task Team,

2. Source of data about NOAA's ecosystem research and science enterprise, how it is organized and how other Agencies (US and foreign) organize similar types of scientific activities,

3. Site visits,

4. Mechanism for public input,

5. "Ground truthing" the review,

6. Timetable.

These aspects are addressed below.

Role of the NOAA Internal Ecosystem Research and Science Task Team: The internal task team will work with the Ecosystem Research and Science Review Team to facilitate gathering data and arrangements for review activity, as one source of ideas and insights, and to act as a sounding board for ideas. The communications between the Internal and External teams should be two-way. A "sounding board" suggests the internal team merely responds to ideas from the external team; whereas it is expected that the internal team already has enormous expertise regarding the issues specified in the Terms of Reference. The internal team will be encouraged to propose ideas (about both problems and potential solutions), not just respond to ideas from then external team. However, it will be solely the role of the "External Ecosystem Research and Science Review Team" to formulate conclusions and recommendations.

Source of data about NOAA's ecosystem research and science enterprise: how it is organized and how other Agencies (US and foreign) organize similar types of scientific activities: Data assembled for the NOAA Research Review (http://review.oar.noaa.gov/) will be updated and refined to serve the specific needs of an ecosystem review. The data will include descriptions of:

1. Ecosystem research and science program elements including budgets and staffing levels,

2. Current organizational structures,

3. Partnerships including university relationships,

4. Scientific activities by facility (e.g., laboratory) and organizational structure,

5. Science user needs, given that the needs of users of "ecosystem science" are expected to be a complex issue.

6. Government Performance and Results Act (GPRA) requirements,

7. Planning and programming documents (e.g., 5-Year Research Plan, 20-Year Vision, Program Baseline Assessments),

8. Other subjects of interest to the External Ecosystem Research and Science Review Team.

It is also important for the Review Team to gather information about organizational approaches of other organizations that have similar missions to NOAA's ecosystem stewardship mission. This might be done by sampling websites (which usually describe organizations), conducting a survey, and/or by interviewing leaders of organizations other organizations. The international experience is particularly important. It is likely that NOAA can profit by learning how other national and multi-national groups are successfully conducting applied marine ecosystem science.

Site visits: The Review Team should make site visits to representative locations (e.g., in terms of Line Office activities, mission areas, scientific disciplines) where ecosystem research and science activities are conducted. These visits should sample activities of NMFS, NOS and OAR. Seattle and South Florida are obvious candidates to be visited, as these are areas where ecosystem sciences are concentrated. Given the relatively large number of NMFS facilities, additional site visits to key facilities are suggested (Woods Hole and La Jolla are good candidates). Charleston is a location where NOS ecosystem science activity is concentrated such that it is a good candidate for a site visit.

Opportunity for public input: Meetings should be arranged with stakeholders, Congressional staff and officials of the Office of Management and Budget. It should be feasible to coordinate stakeholder meetings with the aforementioned facility site visits. Written input might also be solicited by Federal Register Notice. Phone interviews of key constituency spokespersons might be conducted. The draft report will be made available for public comment by publishing it in the Federal Register.

"Ground truthing" the review: There is always a risk that the external review team will come to conclusions or make recommendations that are clearly invalid or unworkable. This usually occurs because the reviewers lack some information or background. Unfortunately, such situations tend to discredit reviews and they are used to dismiss even sound conclusions and recommendations. Therefore, it is prudent to have a knowledgeable group provide feedback on conclusions and recommendations before the report of the review is finalized. This is a role that the Internal Task Team can fulfill at the discretion of the external review team. The external review team may also seek feedback from elsewhere. Ultimately, the conclusions and recommendations must be solely the responsibility of the external review team.

Timetable: The External Review of NOAA's Ecosystem Research and Science Enterprise should be conducted according to the following schedule:

1. Review "clock" starts when SAB agrees to Framework for the review;

2. By day 10, Federal Register Notice (FRN) soliciting nominations published;

3. By day 30, nominations due to SAB;

4. By day 45, members of the external review team selected;

5. By day 75, initial meeting of external review to become familiar with their charge, and to decide on a course of action;

6. Approximately every 45 days after the initial meeting throughout the period of the review, external review team meetings. The internal task team will be available to participate;

7. By day 100, data about NOAA's ecosystem research and science enterprise collected;

8. By day 150, information on organizational structures used by other entities with similar ecosystem stewardship missions to NOAA's collected;

9. By day150, site visits and constituency input sessions have been conducted,

10. By day 150, progress report submitted to SAB;

11. By day 180, interim report submitted to SAB;

12. By day 195, interim report made available in Federal Register for public comment;

13. By day 215, FRN public comments due;

14. By day 230, feedback from SAB to external review team;

15. By day 260, external review team finalizes its report, including "ground truthing;"

16. By day 285, SAB reviews and approves report;

17. Days 286-300, set aside as a contingency in case of unavoidable delays.

If the "clock starts" by the end of November 2004, the review should be complete by the end of the fourth quarter of FY 2005, as called for in the NOAA response to the RRT report. However, the schedule is extremely tight, such that delays in starting the clock will make it unrealistic to complete the review by the deadline without seriously jeopardizing quality.

Annex 1 Extracts from NOAA Research Review Team report relevant to the location of ecosystem research

“We also find that there is a difference between operational responsibilities and regulatory responsibilities. …In mission areas like fisheries, coastal zone management, or more generally ecosystem-based management, NOAA must provide the best advice on which to base management and regulatory decisions. This scientific advice (e.g. fisheries stock assessment) is best based on work in a research environment. … NOAA must exercise caution to ensure that the research program is not unduly influenced by regulatory responsibilities, but at same time, it is essential to ensure that the best science is available and responsive to policy and management needs including the regulatory process.”

“Maintaining the research program within NOS and NMFS with appropriate safeguards for the higher-risk, more basic research efforts can do this. It can also be accomplished by having the research in a separate organizational structure with clear and unambiguous responsibility to meet management and regulatory needs. The Review Team notes that the former approach facilitates the provision of scientific advice for management, but the latter approach may provide a more integrated research effort and enhance extramural involvement.”

“…we note that the research being conducted in NMFS and NOS could migrate to OAR, but only if the scientific advice associated with ecosystem-based regulatory responsibilities went with the research role.”

“NMFS organization into regional fisheries Science Centers is a useful model for interaction and management of laboratories within regions. In each of the fisheries Science Centers there are several laboratories, each with a specific focus area, but they are managed and administered collectively through the Center. This model could, also, be an effective means of integrating the science and research efforts across the line offices.”

Annex 2 Categories of scientific activity

Observational systems: Ecological observations are the core of the research and science enterprise. They are reoccurring measurements of ecosystem variables (which throughout this document should be understood to including the human dimension) that build time series. Standard procedures (including protocols for quality assurance and data management) are in place for research and scientific activity in this category. The data is used for a variety of purposes, such as input into advice on resource management decisions. While some of the data is used for documents published in the scientific literature, it is also found in advisory products aimed a decision makers, distributed in technical reports, and made accessible in databases.

Scientific advice and information products: These are science-based analyses (both qualitative and quantitative) aimed at reporting on the state of ecosystem variables, the consequence of human activities, and the implications of alternative management decisions. Generally, assessments are tailored to the needs of non-scientific users. They depend heavily on observations and understanding of ecosystem processes obtained through applied research. Assessment results are usually reported in technical documents tailored to user needs. They are also used by researchers conducting syntheses on the state of ecosystems and case studies on the performance of resource management.

Applied Research: This research is mission inspired even though it may be long term without an immediate connection to non-scientific users. It is aimed at advancing understanding of aspects of marine ecosystems with a view at enhancing the capability give scientific advice and provides information products. This research tends to focus on processes that govern populations and ecosystems. It also includes research that improves understanding of technologies, thus leading to development that supports the mission. The primary outlet for this research is the scientific literature. Other scientists are typically the users.

Development: This activity uses the increased understanding produced by the Agency's applied research, and any other pertinent research, to create new tools or methods to increase the capability and/or capacity to provide scientific advice and services to non-researchers. Nevertheless, successful development is usually documented in the scientific literature. It does not include development primarily aimed at research applications (this activity is part of strategic research). There are three subcategories of Development:

- Development of Science Tools: Development of science tools provides new applications of technology for observing or new methods (such as models) for assessments.

- Development of Conservation Technologies: This development is of new technologies that help to minimize undesirable impacts of human activities on marine ecosystems. This development provides new options for regulating human activities to achieve conservation objectives, without undue negative impact on benefits from the regulated activities.

Development of Production Technologies: This activity provides new options for deriving benefits from human activities associated marine ecosystems. If successful, these technologies will be adopted by the private sector without regulatory requirements (e.g., the private sector has an economic incentive to use the technologies

APPENDIX 3. ECOSYSTEM SCIENCE CAPABILITIES REQUIRED TO SUPPORT NOAA'S MISSION IN THE YEAR 2020

This appendix was developed to provide additional strategic input to the External Ecosystem Task Team (eETT), by examining a number of pivotal issues that will require greater emphasis over the next 15 years, as NOAA, its partners, and its customers more fully implement ecosystem approaches to management. In order to achieve this goal, NOAA must consider the portfolio of critical research and monitoring capabilities necessary to support stewardship and management of its trust resources. These six white papers are not intended to be comprehensive with respect to all the existing and emerging issues, but rather focus on areas where current research and management trends indicate obvious needs for combining some of NOAA's assets to focus on broad cross-cutting themes. The issues addressed in the six white paper themes were originally identified by the eETT and the internal ecosystem task team (iETT) members, and were assigned to groups of NOAA's senior scientists and research managers who are at the forefront of these issues, and who represent a cross-section of the various line offices collaborating on the issues. The six white papers themes consider:

The eETT appreciates the efforts of the 36 individuals authoring and many others reviewing the White Papers.

Ecosystem White Paper #1

Ecosystem Responses to Climate Variability

Writing Team:
Kenric Osgood, NMFS, Office of Science and Technology
Ned Cyr, NMFS, Office of Science and Technology
Tom O'Connor, NOS, National Centers for Coastal Ocean Science
Jeff Polovina, NMFS, Pacific Islands Science Center
David Schwab, OAR, Great Lakes Environmental Research Laboratory
Phyllis Stabeno, OAR, Pacific Marine Environmental Laboratory

I. Description of the Issue:

IV. Background

Variations in the world's climate have significant implications for the productivity and structure of marine and coastal (including Great Lake) ecosystems ranging from the tropics to the poles. Climate-driven variability of environmental conditions is manifest on many time and space scales, including year-to-year variation, multi-year (e.g. El Niño-Southern Oscillation [ENSO]), and decadal scales (e.g., Pacific Decadal Oscillation [PDO], North Atlantic Oscillation [NAO], Arctic Oscillation [AO]). In addition to this shorter-term variability, the Earth's climate system has demonstrably warmed on both global and regional scales since the pre-industrial era, impacting ice extent (IPCC, 2001). As a consequence of global warming and subsidence, sea levels continue to rise and the rate of rise is projected to accelerate. Precipitation and resulting rates of runoff are predicted to change significantly over the next century. These variations and changes in environmental conditions have profound implications for ecosystems and the human activities that are dependent on them by changing the distributions and productivity of living resources.

Climate changes potentially have large impacts on living marine resource populations including the Great Lakes (McGinn, 2002). Along the U.S. west coast El Niño events cause shifts in population distributions of many marine species and greatly impact ocean productivity (Pearcy and Schoener, 1987), while decadal scale climate shifts impact the structure and productivity of North Pacific and Bearing Sea ecosystems (Hollowed and Wooster, 1992; Hare and Mantua, 2000; Peterson and Schwing, 2003). Shifts such as the change from shrimp to groundfish dominance in the Gulf of Alaska in the late 1970s reflect decadal changes in ocean climate (Anderson and Piatt, 1999), as do large shifts in Pacific salmon production (Mantua et al., 1997). The Bering Sea is undergoing a northward biogeographical shift in response to changing temperature and atmospheric forcing (Overland and Stabeno, 2004) and in the North Atlantic many marine fish species have been observed to shift their distributions poleward in response to increases in water temperature (Murawski, 1993; Parker and Dixon, 1998; Perry et al., 2005). Long-term declines in krill stocks have been observed in the Southern Ocean and links between annual krill density and sea-ice cover have been established (Atkinson et al., 2004). Similarly, in the Bering Sea and Arctic Oceans, reductions in sea ice coverage have negative implications for ice dependent species, but positive implications for other species that may be able to take advantage of the changing conditions, thus having consequences that cascade through the food webs (ACIA, 2004). Changing climate forcing affects important physical features in the ocean, thereby impacting marine species that take advantage of these features. For example, the Transition Zone Chlorophyll Front (TZCF) is a sharp boundary in the waters north of the Hawaiian Islands between the stratified, low surface chlorophyll water and the cooler, vertically mixed, high surface chlorophyll water. This productive feature is used as a migration pathway by sea turtles and tunas (Polovina et al., 2001) and its winter location appears important to survival of monk seal pups. Climate change will also influence the thermal regime in the Great Lakes, impacting the growth rate potential of important fish species (Brandt et al., 2002).

Rising sea level directly impacts coastal ecosystems (Boesch et al., 2000), inundating wetlands and shallow water habitats and increasing, salinity, wave action, and storm surges. In regions where coastal development interferes with the landward migration of coastal ecosystems as sea level rises, the ecosystems may disappear. Shifts in precipitation change the amount, timing and contents of freshwater runoff – impacting coastal and estuarine areas (Boesch et al., 2000). For example, the large hypoxic zone that occurs each summer over the northern Gulf of Mexico shelf may increase in size and intensity if runoff from the central U.S. increases (Justic, 2003). Rising temperatures have implications for the productivity and viability of coral reef ecosystems as mass coral bleaching has occurred in association with episodes of elevated sea temperatures (Hoegh-Guldberg, 1999). Coral reefs, and other calcifying marine organisms including important plankton components, are also susceptible to anthropogenic ocean acidification due to increasing CO_2, decreasing their ability to build their $CaCO_3$ structures (Feely et al., 2004, Orr et al., 2005).

There exists the need for science to identify how climate variability impacts ecosystems and how different ecosystems respond to climate forcing, to differentiate the impacts of short term variability (year-to-year, multi-year) from longer term variability (decadal and longer), and to identify the most cost-effective ways to adapt to the changes or reduce the risk of negative impacts. Without this information, society cannot rationally assess the costs and benefits of policy options to mitigate the impacts of climate variability or adapt human uses to account for the magnitude and timing of climate-induced changes.

NOAA's Role in Framing Climate-Ecosystem Issues:

NOAA has responsibilities to monitor, understand and predict the impacts of global climate change on marine and coastal ecosystems. Specifically, NOAA has responsibilities to:

- monitor and model changes in coastal production as a consequence of predicted climate changes in the rate and amount of runoff and in the timing of spring phytoplankton blooms;

- evaluate and predict climate impacts, including increases in CO_2, on coral ecosystems;
- adapt how it manages marine fisheries, marine mammals and protected marine species by accounting for the impacts of climate variability and change on marine ecosystems;
- utilize predictions of climate status to forecast the impact of such change on coastal ecosystems.

As an agency, NOAA has the capabilities and legislative mandate to exert leadership in conducting this work. Without NOAA investment, society's ability to adapt to changes in coastal and marine ecosystems will be severely limited.

To address these needs NOAA has identified the following high priority topic areas:

Climate regimes and ecosystem productivity: Profound shifts in biological productivity, species distributions, and ecosystem structure are often ecological responses to climate variability, and are of great consequence to fishery-dependent communities and the commercial fishing industry. Projects within this topic aim to predict the probable consequences of climate change on coastal and marine systems and the living resources contained therein, and to provide the knowledge and tools needed to incorporate climate variability into the management of living marine and coastal resources. This topic area entails a wide variety of projects to investigate and provide a predictive capability of the impacts of changing climate on coastal and marine ecosystems. In addition to projects focused on what have become known as climate regime shifts, e.g. ecosystems alternating between anomalous warm and cool states (Hollowed and Wooster, 1992), this topic also includes studies to investigate: coastal and marine ecosystem impacts from any change in the physical environment due to changing climate; the impact of diminishing ice cover, e.g. impacts diminishing sea ice on marine mammals and fisheries within the Bering Sea ecosystem; and how climate variability and change impact the productivity of Pacific salmon within their oceanic and freshwater habitats.

Coastal response to sea-level rise: To plan development that will protect coastal property and ecosystems, state and local governments need accurate and precise elevation maps showing the extent of coastal inundation due to projected sea level rise. These projects will collect topographic and bathymetric data to create detailed elevation maps, which along with hydrographic modeling comprise precise coastal flooding models (CFMs). While CFMs are required to protect man-made infrastructure, projects under this topic also provide for protecting ecosystems by modeling the responses of the various types of wetlands and shallow water habitats to increases in water depth, salinity, waves, and storm surges.

Nutrient-climate interactions: Climate change models predict major shifts in the amount of precipitation experienced by various regions of the United States. In addition, the coastal glaciers of Alaska are melting. Such changes may lead to increased runoff of freshwater and its nutrients into coastal and estuarine areas, making them more susceptible to eutrophication. For marine systems, this will also enhance stratification, further increasing the susceptibility to eutrophication. These projects will monitor and model changes in coastal eutrophication as a consequence of predicted climate changes in the rate and amount of runoff.

Coral bleaching: Bleaching occurs when corals are stressed by a synergistic combination of stressors, including increases in sea surface temperature. These projects will improve the current network of observational sensors and provide an integrated approach capable of forecasting the time, place and potential severity of coral bleaching events. Successful forecasting of coral bleaching events will allow managers and stakeholders to prepare for, forestall and/or ameliorate the devastating effects of bleaching on coastal ecosystems and resource loss resulting from bleaching events.

Decalcification: The carbonate equilibrium of the oceans is shifting in response to increasing atmospheric CO_2 concentrations. There is also mounting evidence that calcification rates of several major groups of marine calcifiers, including shallow and deep water corals and calcifying plankton, will decrease as CO_2 concentrations continue to rise. Many of these organisms are of direct economic importance to human populations, while the others are important through their significance within the marine food web. Projects within this topic will gain a better understanding of how ocean biology and chemistry will respond to higher CO_2 and concomitant lower pH conditions so that predictive models of these processes and their impacts on marine ecosystems can be developed.

Influences external to NOAA that will drive future needs:

It is increasingly apparent that coastal and marine ecosystems are not in steady state and that resource managers must be prepared to adapt to changing conditions. In addition to the importance of annual to decadal scale climate variability to ecosystems, global climate change is predicted to have increasingly significant effects over the next 15 years. Such change will impact both the mean state of the environment and its variability. By not accounting for climate variability and change parameters in advice to resource managers, NOAA risks providing management advice that does not match evolving environmental conditions and thereby risks mismanagement of coastal and marine ecosystems. Since any large-scale climatic change will result in both winners (species who do better in a new climate regime) and losers (species who do not thrive under such change), failure to consider climate in management decisions can and will result in over or under harvesting of living resources and poor management of non-harvested species. This will clearly impact not only the ecosystems, but also the people and communities that are dependent upon coastal and marine resources. Long range planning will be improved if a predictive capability for climate impacts on ecosystems is developed. Accounting for climate variability and change is an important component of implementing an ecosystem approach to marine resource management as called for in the Ocean Action Plan. In the coming decades, as anthropogenic stressors continue to build on coastal and marine ecosystems through coastal development and resource exploitation, climate impacts are likely to become increasingly important. Through studies to monitor, understand and predict the impacts of global climate change on marine and coastal ecosystems, NOAA will address needs identified in the U.S. Climate Change Science Program (CCSP) Strategic Plan.

II. Science Capabilities Necessary to Support Future Decision Making

A. Present capabilities

NOAA has made large investments towards understanding the physical climate system and describing the mechanisms that govern climate variability and change. However, very little work has been done to understand the impacts of climate variability or the implications of future climate change on coastal and marine ecosystems. For this reason, NOAA initiated a Climate and Ecosystems Program with the objective of understanding and predicting the consequences of climate variability and change on marine ecosystems. Its strategy is to develop the ability to predict the consequences of climate change on ecosystems by monitoring changes in coastal and marine ecosystems, conducting research on climate-ecosystem linkages, and incorporating climate information into predictive physical-biological indicators and models.

The Climate and Ecosystems Program was initiated in FY 2004 with one project. This project, North Pacific Climate Regimes and Ecosystem Productivity (NPCREP), is building an understanding of how climate fluctuations and change affect the eastern Bering Sea and Gulf of Alaska ecosystems. NPCREP is utilizing a combination of retrospective, monitoring, process and modeling studies to advance the understanding of the impacts of climate on the fisheries in the region, thereby generating the necessary foundation for understanding climate-ecosystem relationships. Through the increased understanding being obtained, NPCREP is developing indicators of climate impacts and models to predict the probable consequences of climate change on the eastern Bering Sea and Gulf of Alaska ecosystems. These products are delivered to fisheries managers at the North Pacific Fishery Management Council so that climate variability and change can be incorporated into the management decisions affecting the living marine resources in these regions.

NOAA also has projects outside of the Climate and Ecosystems Program related to the impacts of climate on marine ecosystems.

- NOAA has helped support U.S. GLOBEC (Global Ocean Ecosystems Dynamics) projects in the Georges Bank/Northwest Atlantic Region and the Northeast Pacific (with components in the California Current and the Coastal Gulf of Alaska). GLOBEC is a research program that addresses how global climate change may affect the abundance and production of marine animals.
- NOAA began a project in 2004 to create coastal flooding models with a precision of 20 cm in order to map coastal inundation under the existing and any projected rate of sea level rise. Included is an ecological component to model changes in coastal habitats as a function of rates of sea level rise and landscape characteristics. These models are designed for local managers to adapt coastal development plans to accommodate sea level rise and its ecological consequences.

- NOAA's Coral Reef Watch project has developed a variety of satellite and *in situ* based products that monitor the environmental conditions of coral reef ecosystems and is linking ecosystem models with current and past climate data to enable understanding of the relationship between climate parameters and coral ecosystem response.
- Numerous individual investigators incorporate indices of environmental variation when various assessments of the status of living resource populations are developed. Some of these investigations are sophisticated, insightful and are providing useful information with which to provide strategic guidance to managers. These efforts, however, are often fragmented and not well coordinated to assure information exchange and use of most appropriate data products and models.
- There is no ongoing NOAA project addressing the effect of climate change on coastal eutrophication or modeling activity directly predicting the locations and intensity of climate-driven coastal eutrophication. However, existing monitoring programs making *in situ* or satellite-based measurements of water quality and chlorophyll concentrations are beginning to create the long-term database required to document responses to climate change.

B. New or enhanced capabilities that will be required

Enabling the incorporation of climate impacts into management plans, through predicting the probable consequences of climate variability and change on coastal and marine ecosystems and delivering the knowledge and predictive tools to managers, is essential. To support these products and services NOAA needs to: 1) expand its capability to develop biophysical indicators and models that meet the needs of coastal and marine resource managers to adapt to predicted climate-induced changes in fishery, coastal, and coral-reef resources; 2) expand its capability to monitor changes in coastal and marine ecosystems through a network of *in situ* and remote observing systems; and 3) gain an understanding of the mechanisms and rates that control ecosystem response to climate variability and change. Predictive biophysical indicators and models will allow for the proactive management of living resources, the most efficient manner in which to manage resources. Monitoring changes in ecosystems will allow for reactive management and provide data essential for the development of indicators and models. Understanding the mechanisms and rates that control ecosystem productivity and energy flux is critical for the development of predictive indicators and models.

NOAA requires an integrated climate-ecosystem observing system to provide climate variability data and synoptic ecosystem structure and productivity information. Such input parameters would be used to document ecosystem responses to climate changes, to develop a better understanding of climate effects on ecosystems, and to develop more timely biophysical indicators and models that support management and policy actions. Additional days at sea aboard next-generation oceanographic and fisheries survey vessels are required to make the critically needed observations (deployment of moorings and satellite-tracked drifters and hydrographic, fish stock, protected resource and plankton surveys) and to conduct at sea research to understand the processes and mechanisms of climate impacts on ecosystems.

Ocean models will be important tools to investigate and describe physical and biological responses resulting from climate variability. Currently both basin-scale and regional ocean models are being used as research tools to describe ocean responses resulting from recent climate variability. Some of these ocean-atmosphere coupled models also include a lower trophic level component to describe spatial and temporal aspects of plankton dynamics. A priority of future research will be to ground truth the output from these models and develop approaches to directly or indirectly extend them to address higher trophic level dynamics. The development of spatially resolved models to predict and assess the implications of climate variability and change on ecosystems is crucial for planning adaptation strategies. These predictive models will provide a framework within which mitigation or adaptation strategies and policy options can be explored.

C. Science and research needed to support these capabilities

There are no major technological hurdles that need to be overcome to achieve better understanding and more accurate and precise predictive capability of ecosystem responses to climate variability and change. That being said, there will, however, be great benefit from new observation technologies and advances in modeling techniques. However, the conceptual understanding of the mechanisms through which climate impacts ecosystems needs to be improved if a predictive ability is to be achieved. This requires process-based research focused on gaining a better understanding of the linkages between climate forcing and ecosystem responses at various time and space scales. This understanding is essential to enable the development and testing of indicators of climate impacts on ecosystems and models to predict the probable consequences of climate variability and change on particular regions. Without the knowledge of the mechanisms linking ecosystem responses to climate, we will be forced to rely on correlations between climate forcing and ecosystem responses, in the absence of an understanding of causation. Often, these correlations break down over time because there is no mechanistic link between the parameters. They will almost certainly break down under changed climate forcing, since the linkages between the critical mechanisms that impact productivity will likely change.

V. III. Partnerships Necessary to Effectively Address the Emerging Issue

To effectively address the impacts of climate on marine ecosystems NOAA must partner with other federal agencies, as well as state and local agencies, leveraging their expertise and resources. Coordination of programs at the federal level is conducted through the Ecosystem Interagency Working Group of the U.S. Climate Change Science Program.

NOAA utilizes knowledge gained on ecosystem responses to climate variability within the U.S. and from around the world by academia, government agencies and programs, and other entities. NOAA investigators, along with partners from universities and private industry who are supported by research grants, conduct the single existing project within NOAA's Climate and Ecosystems Program. A significant portion of the funding for all proposed Climate and Ecosystems projects would support academic researchers through grants in order to enhance collaborations and provide necessary scientific expertise. In addition, due to the scope of the information needed to address the questions of the program, a wide range of linkages and partnerships with other programs are necessary. For example NPCREP, the existing Climate and Ecosystems project, is linked with other NOAA projects, IOOS through the Alaska Ocean Observing System (AOOS) and the Northwest Association of Networked Ocean Observing Systems (NaNOOS), and programs supported by other agencies and NGOs (e.g. programs supported by the National Science Foundation, the North Pacific Research Board, and the *Exxon Valdez* Oil Spill Trustee Council). NOAA's work on developing coastal flooding models for a portion of the coast of North Carolina, work that could evolve into a national effort, requires the active participation of scientists with local knowledge and state support in obtaining precise topography. NOAA's monitoring of coastal eutrophication within the National Estuarine Research Reserves is done in partnership with states.

VI. IV. Benefits to NOAA, Constituents, and Society in General from this Effort

There are significant benefits to be derived from better understanding and forecasting the ecosystem responses to climate variability. Projects within this topic have a high potential to positively impact management of these ecosystems and will also span a wide range of other beneficiaries. They will enable NOAA to address the urgent and continuing needs of managers of living resources and will move NOAA toward its stated goal of ecosystem-based management. NOAA will observe, understand, and predict ecological effects of climate variability and change on major coastal and marine ecosystems of the United States. Users will be provided the information needed for decisions about responses of living marine resources and coastal zones to climate-induced perturbations. Consideration of the potential impacts of climate variability on ecosystems and coastal zones will become an explicit component of living marine resource and coastal zone management plans.

The predictive information provided will enable fisheries managers to more accurately predict the optimum yield for fishery stocks, thereby minimizing the amount of unrealized harvest or over harvesting of species. This information will allow managers to modify fishing effort, timing or location for particular species, change the gear type used, or change which species are targeted for a region. This information will also help fishermen with their fishing strategies and their equipment investment planning, thus benefiting fishery-dependent human communities. The knowledge and predictive tools generated by these investigations will be of great value to the management of marine mammals and other protected species, ensuring that potential direct and indirect climate impacts on their populations are accounted for.

Coastal managers would benefit from the development of precise maps of predicted coastal inundation due to climate induced sea level rise, models of ecosystem responses to increased water depth and salinity, and models of changes in coastal eutrophication as a consequence of climate variability. With these models, coastal managers can plan development that will have minimal impact on coastal ecosystems, taking into account climate impacts.

Managers of coral reef resources would benefit from predictions of climate impacts on coral reefs by allowing them to quantify the risk of different reefs to climate impacts, identify regions to maximize conservation, and reduce other stressors on reefs during predicted times of increased climate induced stress. These predictions will also help us better understand the little understood, cold water corals that are found within U.S. waters.

Climate variability and change have significant implications for the distribution and abundance of species and for the productivity and functioning of ecosystems as climate sets the boundaries within which species are adapted. As species are excluded from presently inhabited geographic regions due to changed climate, some may disappear completely while others may shift their geographic distributions if there is sufficient time and habitat. In regions where major species shifts occur, the newly structured ecosystems may be more or less productive than the present ones, but we can be assured that management policies adapted for the present ecosystem will not apply in the changed ecosystem. Changes in these ecosystems and their management will have a great impact on human communities and sectors dependent upon susceptible living marine resources.

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PRELIMINARY REPORT

Ecosystem White Paper #2

Management of Living Marine Resources in an Ecosystem Context

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I. Description of the Issue

One of the four goals articulated in NOAA's Strategic Plan is to "protect, restore and manage coastal and ocean resources through an ecosystem approach" (NOAA, 2004). This goal flows from the mandates and direction of such federal laws, executive orders, courts, and international treaties as the Magnuson-Stevens Fishery and Conservation Management Act, Endangered Species Act, National Environmental Policy Act, Marine Mammal Protection Act, Coral Conservation Act, ICCAT, IATTC, Coastal Zone Management Act, and National Marine Sanctuaries Act. These are expressions of society's desire for policies and institutions for managing the environment. When combined, they reflect the recognition that fishing is but one competing use of ecosystems that produces a broad set of ecological and societal benefits. But the benefits are not achieved without costs; thus, the need for managing living marine resources (LMR) in an ecosystem context. The critical need for a more holistic approach to managing the use of LMRs has been well articulated in a number of recent publications, including US Commission on Ocean Policy Report (2004), US Ocean Action Plan (2004), PEW Ocean Commission Report (2004), Rappoport (1998), Report to Congress by the ecosystem principles advisory panel (1999), FAO (2003), a series of essays published by the Marine Ecology Progress Series (Browman and Stergiou 2004), a series of NRC publications (1994, 1999a, 1999b, 2001, and 2002), as well as numerous references contained therein.

The NOAA Perspective on Management of LMRs:
There are more than 90 Congressional Acts, treaty obligations, Executive Orders, regional agreements, NOAA-specific policies, memoranda of understanding with other federal agencies, and court orders that drive the requirements of NOAA's Ecosystem Mission Goal (NOAA 2005a). Over the last 20 years, NOAA has been actively working to establish scientific underpinning for an ecosystem approach to management of coastal and ocean LMRs, so that complex societal choices are informed by comprehensive and reliable scientific information (NOAA Report – *Understanding Global Ecosystems to Support Informed Decision-Making*, 2005b). The types of products and services NOAA intends to provide to constituents and Agency managers include: (1) forecasts and mitigation strategies related to harmful algal blooms, invasive species, and air/water

quality, (2) ecological assessments and predictions of impacts from climate change on ocean productivity (e.g., see White Paper #1, examples include coral bleaching, loss of sea ice in the Bering Sea and others), (3) decision support tools for adaptive, ecosystem-based management of fisheries, coastal development and other marine resources, (4) improved assessments of sea level change on coastal resources and ecosystems, (5) better integration of observing system data for use by managers responsible for the health of coastal ecosystems, and (6) fishery productivity forecasts that incorporate the effects of climate change.

For each of these products (e.g., forecasts, assessments, decision support tools, etc.), it will be necessary to take account or otherwise incorporate uncertainty associated with parameter estimation and process error (e.g., uncertainty of how a change ion one component of an ecosystem influences the others). This is typically done by evaluating the performance of competing approaches using output from computer simulations that are run under a wide range of scenarios (FAO 2003: p. 58). Field data collected in support of these models is often not collected from a wide variety of system states, so there must be inference regarding underlying processes dictating prey switching by predators, etc. The evaluation of performance must be closely coordinated with resource managers and policy makers. Such an approach has become one of the basic tenets of an ecosystem approach to management by many national and international organizations. By necessity, it requires discourse between researchers and managers, and in the future, NOAA will need to increasingly incorporate constituent input into this discourse. The key assumption under this approach is that management tools that do not perform well in computer simulations are very likely to fail in the real world. That doesn’t mean that management tools that perform well will necessarily produce satisfactory results in the real world, but they are certainly more likely to be successful than non-tested management approaches. One form of decision support tools used to evaluate the impacts of harvest policy is a management strategy evaluation (MSE). The National Environmental Policy Act requires that agencies conduct this type of review to provide public disclosure of potential impacts of management actions. The MSE is an attempt to provide quantitative rather than qualitative information for decision makers. Thus NOAA scientists play a crucial role in the process by providing the analysis tools and forecasts that will facilitate collaborations between managers, researchers, and constituents that will encourage the development of harvest policies with full knowledge of the necessary trade-offs between the likelihood of sustainable use of a living marine resource, its community, or its ecosystem and the likelihood of acceptable social or economic performance.

A common lexicon for usage of ecosystem concepts

NOAA has adopted a common lexicon across its various line offices to promote a shared understanding and usage of ecosystem concepts. For the purpose of this document (NOAA 2004 and FAO 2003):

> An *ecosystem* is a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.

> The *environment* is the biological, chemical, physical, and social conditions that surround organisms. When appropriate, the term environment should be qualified as biological, chemical, physical, and/or social.
>
> An *ecosystem approach to management* (EAM) is management that is adaptive, geographically specified, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives.
>
> A *fishery* can refer to the sum of all fishing activities on a given resource. It may also refer to the activities of a single type or style of fishing on a particular resource. The term is used in both senses.

The phrase "ecosystem approach to management" (instead of "ecosystem management") is used throughout the document in deference to the preferred international convention. An EAM is incremental, as neither the scientific nor fiscal underpinnings are usually in hand to fully implement ecosystem approaches overnight in every location. LMR management changes ecosystems and their components. Specifying goals for the condition of LMRs, the ecosystem of which they are a part, and the human enterprise of fishing is a prerequisite to the success of this management. An *a priori* assessment of possible ecosystem states must become the foundation for the selection of preferred management actions.

Progress towards implementing an ecosystem approach to managing LMRs can occur in stages along a continuum. For example, management under an ecosystem approach can be categorized into at least three levels. The first level is single species management of targeted resources, with issues of protected species, non-target species, habitat, and species interactions incorporated as important considerations. The second level is a multi-species aggregate and system level approach. This brings in important ecological and environmental factors, such as trophic structure, carrying capacity, climate anomalies or regime shift influences, on the condition of the ecosystem. The third level is a comprehensive, multiple *sector* approach that captures activities and values associated with all external influences (fishing and non-fishing sectors) that impact the condition and sustainability of ecosystems (not just focusing on living marine resource conservation or extraction, but including uses of and impacts on marine ecosystems by transportation, military, and oil and gas sectors, for example).

Background Information:
A number of quotes from recently publications serve to provide perspective and approach on how LMRs will be managed in an ecosystem context in the next 15 years:

1. Report to Congress by the Ecosystem Principles Advisory Panel (1999): "*The benefits of adopting ecosystem-based fishery management and research are more sustainable fisheries and marine ecosystems, as well as more economically-healthy coastal communities. We have identified actions required to realize these benefits. We* *urge the Secretary and Congress to make those resources available*." The eight ecosystem principles recommended by the Panel are presented in Appendix A.

2. Murawski (2000): "*Ecosystem considerations may be incorporated into fisheries management by modifying existing overfishing paradigms or by developing new approaches to account for ecosystem structure and function in relation to harvesting. Although existing concepts of overfishing have a strong theoretical basis for evaluating policy choices and much practical use, they do not provide direct guidance on issues such as biodiversity, serial depletion, habitat degradation, and changes in the food web caused by fishing.*" and "*Ecosystem considerations do not need to substitute for existing overfishing concepts. Instead, they should be used to evaluate and modify primary management guidance for important fisheries and species*."

3. Clark et al. (2001): "*Planning and decision-making can be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Availability of new data sets, together with progress in computation and statistics, will increase our ability to forecast ecosystem change. An agenda that would lead toward a capacity to produce, evaluate, and communicate forecasts of critical ecosystem services requires a process that engages scientists and decision-makers. Interdisciplinary linkages are necessary because of the climate and societal controls on ecosystems, the feedbacks involving social change, and the decision –making relevance of forecasts.*"

4. Hilborn (in Browman and Stergiou [2004]): "*No one questions that the majority of the world's fisheries are heavily used, many are overfished, some have collapsed, and good biological and economic management suggests substantial reductions in fishing pressure are needed for sustainable management.*"; "I*, and others (Garcia et al. 2003, Sissenwine & Mace 2003), believe that we need a form of ecosystem management that emphasizes the interaction between fish, fishermen and government regulators and concentrates on incentives and participation with user groups. This difference can be considered as a choice between a participatory approach with incentives as a 'carrot', and a centralized government using regulations as a 'stick'.*"; and "*To argue that we need more data intensive management and more regulation by central governments in the fisheries of the world that have little data and little regulation is untenable*."

5. Pew Ocean Commission (2003): The Pew Oceans Commission identified governance structure as one key issue in developing more robust U.S. fisheries management.

6. Jennings (in Browman and Stergiou [2004]): "*EAF* [Ecosystem Approaches to Fisheries] *is part of the ecosystem approach. The broad purpose of the EAF is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services (including, of course, non fisheries benefits) provided by marine ecosystems.*"

7. Mace (in Browman and Stergiou [2004]): "*The lack of adequate monitoring of marine species, habitats and oceanographic factors is perhaps the most difficult problem of all to address, primarily because of the prohibitive costs associated with conducting surveys of marine resources and the high costs of simply monitoring catches in many countries. Realistic cost-benefit analyses may well indicate that the costs of comprehensive scientific research far exceed both short- and long-term potential economic benefits to the fishing industry. As a result, while a few countries may be* *improving their monitoring capabilities (e.g. the United States), others are losing funds for research and monitoring. Recent progress includes several ambitious programs under the auspices of the Global Ocean Observing System (GOOS), Global Ocean Ecosystem Dynamic Programs (GLOBEC), and the Census of Marine Life (CML).*"

8. Sissenwine and Murawski (in Browman and Stergiou [2004]): "*Incorporation of ecosystem-based approaches into fisheries management involves accounting for a number of important classes of interactions that are not routinely evaluated in current species-by-species or fishery-based management programs*."; "*Controlling fishing mortality, and manipulating its application on particular size or age classes, are the keys to achieving the typical objectives of sustainability, high yield, and efficiency. Often, this is done by setting a Total Allowable Catch (TAC) based on the relationship between catch and fishing mortality. Another approach is to limit fishing effort (days at sea or some other effort metric) since fishing mortality is proportional to effort. Controlling fishing mortality through either a TAC or limit on fishing effort requires considerable scientific information about the fishery and resource species.*"; and "*Moving from 'intelligent tinkering' to a more direct focus on ecosystem properties and outcomes will necessarily involve closer ties between science and management.*"

9**. US Commission on Ocean Policy (2004):** "*The many potentially beneficial uses of ocean and coastal resources should be acknowledged and managed in a way that balances competing uses while preserving and protecting the overall integrity of the ocean and coastal environments.*"; and "*Downward trends in marine biodiversity should be reversed where they exist, with a desired end of maintaining or recovering natural levels of biological diversity and ecosystem services.*"

10. Pikitch et al. (2004): "*Protecting essential habitat for fish and other important ecosystem components from destructive fishing practices increases fish diversity and abundance. Thus, ocean zoning, in which type and level of allowable human activity are specified spatially and temporally, will be a critical element of EBFM. … We believe EBFM can be implemented in systems that differ in levels of information and uncertainty through the judicious use of a precautionary approach. This means erring on the side of caution in setting management targets and limits when information is sparse or uncertain. Greater uncertainty would be associated with more stringent management measures. Because ecosystem management involves a wide range of objectives, great ecosystem complexity, and a high level of uncertainty in predicting impacts, EBFM inevitably requires that some level of precaution be exercised. Ideally, EBFM would shift the burden of proof so that fishing would not take place unless it could be shown not to harm key components of the ecosystem. Progression from data-poor to data-rich EBFM will be facilitated by adaptive management and greater understanding of how ecosystems respond to alternative fishing strategies*."

11. Hall and Mainprize (2004): "*In a fisheries context, perhaps the most important discussion of all must be about what constitutes a desirable or an undesirable state for an ecosystem and how one weighs the importance of the various attributes… Identifying stakeholders, distinguishing between fishing and environmental impacts, initiating comprehensive consultations, finding alternative incentives and choosing ideal measures for management are all critical considerations. Only once this is achieved will we be on the road to producing healthy fisheries that are ecologically and economically successful for present and future generations.*"

Overview of Managing LMRs in an Ecosystem Context

There is increasing recognition of the need for management of LMRs in an ecosystem context. Globally, declines in fishery resources, alteration of critical habitats, incidental capture of non-target species, and the effects of climate variability all point to the need for a more holistic approach to understanding human impacts on marine ecosystems and the interplay of natural and anthropogenic agents of change.

The U.S. Ocean Action Plan strongly endorsed the concept of ecosystem approaches to management following the report of The U.S. Commission on Ocean Policy. The Commission noted that:

"*U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including human and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries.*"

The above statement highlights the need to consider the interaction among system components and emphasizes that ecosystem approaches to management are inherently place-based. Because the properties of an ecosystem are different from those of its parts (see text box), an ecosystem approach to the management of LMRs will necessarily differ from traditional single species approaches while maintaining some elements of these approaches.

Harvesting has both direct and indirect effects on marine ecosystems. The former include removal of biomass and potential impacts on habitat and non-target species. The latter includes alteration in trophic structure through species-selective harvesting patterns changing the relative balance of predators and their prey. Multispecies considerations in fishery management account for these interactions for harvested species and the need to consider factors such as the food and energetic requirements of non-harvested species such as marine mammals, seabirds and turtles. Further consideration of the role of habitat in resource and system productivity and the effect of environmental forcing on system dynamics provides yet a more inclusive and necessary ecosystem perspective. Collectively these factors can result in shifts in productivity states that must be accounted for in management. Further, it requires that we explicitly deal with trade-offs in management (e.g. between predators and their prey). The development of a full ecosystem approach to management will require consideration not only of these harvesting impacts but of the effects of factors such coastal development, pollution, shipping, and oil and gas extraction on the integrity of marine ecosystems and resource productivity. A summary of objectives for regionally based ecosystem approaches to management is provided in Appendix B. This summary was developed recently by a Working Group in NOAA Fisheries (NOAA Fisheries 2004).

Spatial Restrictions on Fishing to Manage LMRs

Spatial restrictions on fishing to manage living marine resources have long been recognized and used as tools to reduce or redistribute fishing mortality. However, these restrictions are usually directed at a subset of species, specific fishing gear, and over limited time frames. Seldom has the use of complete and permanent spatial prohibitions on all fishing activity (e.g., Marine Protected Areas or MPAs) been used to manage LMRs (although their use is increasing in recent years). However, in many areas MPAs have been touted as a new way to achieve species conservation. For overfished stocks, reducing fishing mortality will theoretically increase them, but the trade offs regarding ecosystem health and social and cultural benefits between reduced fishing mortality over the entire fishing grounds and no fishing mortality within a prescribed area have yet to be fully evaluated, or demonstrated widely in practice. Further, study of the benefits and costs of imposing the restrictions to implement MPAs for achieving society′s other non-fishing objectives has received little attention. For example, if one were to create a marine protected area in which the take of fish and entry of vessels was prohibited, what would be the result on ships or recreational vessels (non-fishing) that might want to transit the area? Would catch and release fishing be allowed? Would the removal of a submerged ship wreck be allowed? These questions should be addressed within the context of accomplishing multiple, possibly simultaneously competing objectives. In short, using spatial restrictions to manage LMRs should be examined within an ecosystem context and with the MSE tool mentioned above. One suggestion for framing the discussion for each potential spatial restriction (regardless of the specifics) might be:

"How does the spatial restriction on fishing contribute to optimizing (or at least reconciling) the competitive objectives of preserving biodiversity, sustaining fisheries and other uses, and preserving cultural artifacts within a large marine ecosystem?"

Performance Based Management of LMRs

NOAA's goal to "protect, restore and manage coastal and ocean resources through an ecosystem approach" (NOAA 2004), as noted above, will only be achieved in incremental improvements to existing practices. Initially, risk averse management will be based on appropriately conservative harvest levels that will sustain managed species (target species and species incidentally captured), assessment of proposed actions through NEPA reviews, and imposition of time area closures to protect habitats and gear restrictions. Initial management efforts will include limits to anthropogenic effects on the quality (e.g., potential impacts of fishing gear that contacts the bottom on the benthos) and health (e.g., potential impacts of removing 40-60% of the spawning biomass of a target species) of the ecosystem to allow the ecosystem to function in a sustainable manner, while our society derives benefits in the form of food, clothing, medicine, recreation, culture, etc. The following figure is from NOAA's Strategic Plan (2004) and highlights the relationship between the ecosystem mission goal, outcomes and performance measures. Following the figure is a bulletized list of strategies to accomplish the agreed outcome and mission goal.

ECOSYSTEMS MISSION GOAL

OUTCOMES	PERFORMANCE OBJECTIVES
• Healthy and productive coastal and marine ecosystems that benefit society • A well informed public that acts as a steward of coastal and marine ecosystems	Increase number of fish stocks managed at sustainable levels Increase number of protected species that reach stable or increasing population levels Increase number of regional coastal and marine ecosystems delineated with approved indicators of ecological health and socio-economic benefits that are monitored and understood Increase number of invasive species populations eradicated, contained, or mitigated Increase number of habitat acres conserved or restored Increase portion of population that is knowledgeable of and acting as stewards for coastal and marine ecosystem issues Increase number of coastal communities incorporating ecosystem and sustainable development principles into planning and management

1. Ecosystem Strategies (from NOAA's Strategic Plan 2004)

- Engage and collaborate with our partners to achieve regional objectives by delineating regional ecosystems, forming regional ecosystem councils, and implementing cooperative strategies to improve regional ecosystem health.
- Manage uses of ecosystems by applying scientifically sound observations, assessments, and research findings to ensure the sustainable use of resources and to balance competing uses of coastal and marine ecosystems.
- Improve resource management by advancing our understanding of ecosystems through better simulation and predictive models. Build and advance the capabilities of an ecological component of the NOAA global environmental observing system to monitor, assess, and predict national and regional ecosystem health, as well as to gather information consistent with established social and economic indicators.
- Develop coordinated regional and national outreach and education efforts to improve public understanding and involvement in stewardship of coastal and marine ecosystems.
- Engage in technological and scientific exchange with our domestic and international partners to protect, restore, and manage marine resources within and beyond the Nation's borders.

II. Science Capabilities Necessary to Support Future Decision Making

NOAA's ecosystem research portfolio addresses specific management issues, including aquaculture, coastal resource management, corals, fisheries management, habitat restoration, invasive species, protected areas, and protected species. In its most recent 5-year plan, NOAA (2005b) identified 13 areas of key research for the foci of the Ecosystems Mission Goal. These are: (1) study ocean phenomena, (2) study coral ecosystems, (3) promote research on inter-disciplinary and biophysical integration of observation systems, (4) promote technological development, (5) investigate sources, fates, and effects of anthropogenic influences, (6) explore submerged landscapes and the effects of physical changes on coastal and marine ecosystems, (7) map and characterize previously uncharted habitats, (8) develop and demonstrate environmentally compatible culture systems for commercial, overexploited, threatened, and endangered species, (9) forecast and asses temporal scales of ecosystem variability, (10) create biophysical coupled models of water mass movements and their effects on biological productivity (including fisheries recruitment and population distribution), (11) study aquatic biodiversity, (12) understand the dynamics of social and economic systems and their relation to ecosystem management, and (13) conduct interdisciplinary research to better understand marine biological, chemical, and physical processes and their implications for human health.

One way to organize the science capabilities necessary to manage LMRs in an ecosystem context is to consider the framework recommendations of FAO (2003) regarding research needed to implement an ecosystem approach to fisheries management. These include research organized around the following areas: (1) ecosystems and fishery impact assessments, (2) socio-economic considerations, (3) assessment of management measures, (4) assessment and improving the management process, and (5) monitoring and assessment. The FAO perspective on an ecosystem approach to management is fully consistent with NOAA's definition of EAM (i.e., "*Most importantly, the approach aims to ensure that future generations will benefit from the full range of goods and services that ecosystems can provide by dealing with issues in a much more holistic way*" [FAO 2003]. The primary aim of the Agency is to transition from the traditional single species management approach to management in an ecosystem context. Below is a realignment of the 13 areas of key research identified by NOAA in 2005 categorized by the five areas identified by FAO. In addition and as appropriate, we have added science capabilities identified by the FAO that were considered important in managing LMRs in an ecosystem context:

I. Ecosystems and fishery impact assessments
   a. study ocean phenomena
   b. study coral ecosystems
   c. promote research on inter-disciplinary and biophysical integration of observation systems
   d. promote technological development
   e. investigate sources, fates, and effects of anthropogenic influences
   f. explore submerged landscapes and the effects of physical changes on coastal and marine ecosystems
   g. map and characterize previously uncharted habitats

h. forecast and asses temporal scales of ecosystem variability
i. create biophysical coupled models of water mass movements and their effects on biological productivity (including fisheries recruitment and population distribution)
j. study aquatic biodiversity
k. expand knowledge of how fishing impacts target and non-target species and their associated ecosystems

II. Socio-economic considerations

a. understand the dynamics of social and economic systems and their relation to ecosystem management
b. conduct interdisciplinary research to better understand marine biological, chemical, and physical processes and their implications for human health
c. develop appropriate multispecies bio-economic models
d. conduct research into the factors that influence the day-to-day behavior of vessel operators
e. Apply an integrated environmental and economic accounting framework to the assessment and analysis of interactions between fisheries and other sectors of the economy

III. Assessment of management measures

a. develop and demonstrate environmentally compatible culture systems for commercial, overexploited, threatened, and endangered species
b. develop technology in the area of fishing gear and practices to improve gear selectivity and reduce the impact of gear on ecosystems
c. develop procedures to integrate traditional ecosystem knowledge into management
d. identify the species and ecosystems that are suitable for stock enhancements programs
e. assess the potential role of MPAs as a management tool and evaluate their effectiveness where already implemented

IV. Assessment and improving the management process

a. implement research on how to evaluate management performance, how to include uncertainty and risk assessment in management, etc.
b. develop procedures to improve the participatory processes by stakeholders in the management process
c. develop ways to better communicate the implications of different management strategies

V. Monitoring and assessment

a. promote technological development
b. develop simple and efficient appraisal methods
c. develop adaptive management approaches to assist with data-poor situations
d. develop multiple analytical techniques to underpin the decision-making process
e. develop, as possible, a set of generic indicators that can be widely applied to different ecosystems and different fisheries

In addition, NOAA (2005b) has identified four key technology sectors that it depends on to describe, understand, and predict changes in the status of LMRs. These are (1) sensors capable of gathering information on biological, chemical, and physical components of the environment, (2) platforms (e.g., research and survey vessel fleets, unmanned aerial vehicles and autonomous undersea vehicles, aircraft), (3) information technology, and (4) telecommunications. Over the next 15 years, NOAA scientists will exploit these technologies in developing an integrated Global Earth Observing System of Systems (GEOSS), as well as maintaining existing capabilities for monitoring the status of LMRs and the quality of the ecosystems they inhabit.

The research needed to provide NOAA managers with the necessary information to achieve the Agency's stated goals in managing LMRs is taxon specific. That is, commercial fisheries in US federal waters are currently managed under the primary mandates of the MSFMCA. Managers require specific information to meet these mandates. Similarly, marine mammal management policy is codified in the Marine Mammal Protection Act, while sea turtles are primarily managed under the ESA. Again, the information needs of managers are dictated by a combination of mandates found in federal law, regulations, and Agency agreements. In addition, other statutes also direct or otherwise influence the way NOAA manages LMRs.

Appendix C provides an overview of how LMRs are managed in an ecosystem context in the Bering Sea, which provides an example of the integration of (1) research and management and (2) many potentially beneficial uses of ocean and coastal resources.

III. Partnerships Necessary to Effectively Address the Emerging Issue

The intersection of jurisdictions and the overlap of expertise will identify necessary points of coordination among resource agencies, councils, commissions, and institutions for effective ecosystem research and the associated management. These include:

o Federal authorities such as NOAA, Regional Fishery Management Councils, Environmental Protection Agency, Corps of Engineers, U.S. Department of Agriculture, U.S. Fish and Wildlife Service/U.S. Geological Survey, U.S. Department of Defense, National Park Service, Maritime Administration, U.S. Coast Guard, Minerals Management Service, etc.

o State authorities such as universities, colleges, Interstate Commissions, state coastal zone management agencies, state departments of fisheries management, other natural resource/wildlife agencies, etc.

o Local authorities and institutions such as independent research institutions, planning commissions, zoning boards, etc.

o Tribes/tribal jurisdictions.

o International commissions and institutions implementing international science and

Management agreements governing multiple countries, resource management departments of other countries and their associated research infrastructure.

o Management areas such as: marine managed areas (MMAs)/marine protected areas (MPAs); National Wildlife Refuges; National Marine Sanctuaries; National Estuarine Research Reserves; fishery management areas; habitat restoration and special habitat conservation areas; marine mammal management areas; threatened or endangered species management areas; marine parks or historic wreck areas; military exclusion or operations areas; transportation/navigation routes; oil and gas lease areas; and relevant terrestrial and upland protected areas such as parks, coastal reserves, etc.

Management authorities or areas are considered relevant if they contribute directly or indirectly to management or control of at least one of the factors having an impact on the ecosystem management area (see Appendix A for details).

IV. Benefits to NOAA, constituents, society in general from this effort (from the NOAA Strategic Plan [2004])

Coastal areas are among the most developed in the Nation. More than half the population lives on less than one-fifth of the land in the contiguous United States. Coastal counties, including those along the Great Lakes, are growing three times faster than counties elsewhere, adding more than 3,600 people a day to their populations. Coastal and marine waters support over 28 million jobs and provide a tourism destination for 180 million Americans a year. The value of the ocean economy to the U.S. is over $115 billion. The amount added annually to the national economy by the commercial and recreational fishing industry alone is over $48 billion, with an additional $6 billion in direct and indirect economic impacts from aquaculture. With its Exclusive Economic Zone of 3.4 million square miles, the U.S. manages the largest marine territory of any nation in the world.

NOAA has a unique mandate from Congress to be a lead Federal agency in protecting, managing and restoring these marine resources. To meet this mandate, NOAA scientists, specialists, and external partners contribute a world-class expertise in oceanography, marine ecology, marine archeology, fisheries management, conservation biology, natural resource management, and risk assessment. To achieve balance among ecological, environmental, and social influences, NOAA has adopted an *ecosystem approach to management*, as described in the pages above.

NOAA’s mission to conserve, protect, manage, and restore living marine resources and coastal and ocean resources is critical to the health of the U.S. economy. Research producing the best available scientific information is critical to the success of this mission. In addition, NOAA has made a commitment to improve its ability over the next 20 years in predicting the impact of climate change and variability on the productivity and survivability of species important to commercial fisheries and subsistence hunters. Absent this ability, calamitous changes in the abundance or distribution of LMRs will only be identified after the fact (if at all). At this point, there will be no ability on

NOAA's part to mitigate the adverse effects of such changes. It is critical that NOAA develop and implement the research programs necessary to provide reliable predictions regarding LMR availability with adequate lead times to regional managers and constituents.

Finally, developed countries such as the U.S. have a responsibility for stewardship of the marine ecosystem and for setting standards to protect and manage the shared resources and harvests of the oceans. Believing that it is possible to balance sustainable economic development and healthy functioning marine ecosystems, we seek to provide an example for the rest of the world in comprehensively managing resources of the world's oceans and coasts.

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Appendix A. Ecosystem Principles from the Ecosystem Principles Advisory Panel (1999)

Eight Ecosystem Principles

The National Marine Fisheries Service's Ecosystem Principles Advisory Panel (1999) developed the following list of ecosystem principles:

- The ability to predict ecosystem behavior is limited
- Ecosystems have real thresholds and limits which, when exceeded, can effect major ecosystem restructuring
- Once thresholds and limits have been exceeded, changes can be irreversible
- Diversity is important to ecosystem functioning
- Multiple scales interact within and among ecosystems
- Components of ecosystems are linked
- Ecosystem boundaries are open
- Ecosystems change over time

Appendix B. Summary of recommendations from a NOAA Fisheries Working Group on Regional Ecosystem Approach to Management

(1) *Derive the maximum value to society (on a sustainable basis) available from the living marine resources under our stewardship*, subject to sub-goals 2-9 described below. In implementing this overall goal, NOAA Fisheries must:

- Account for other ecosystem goods and services as they affect, are affected by, and are in addition to fisheries.
- Promote participation, fairness, and equity in policy and management development.
- Allocate resource use and non-use among sectors in a transparent, safe and feasible manner.

(2) *Prevent Overfishing*

- Develop and implement conservation and management measures that prevent overfishing of species or species complexes in each region. The objective is to prevent overfishing while achieving, on a continuing basis, the Optimum Yield (OY) from each U.S. fishery.
- Monitor the status of species or species complexes relative to overfishing and overfished limit reference points.
- Develop rebuilding plans for those species deemed to be overfished.

(3) *Protect Sensitive Species*

- Reduce mortality of marine mammals, sea turtles, sea birds and similar protected apex species to a level that is sustainable.
- Develop and implement conservation measures to maintain marine mammals at optimum sustainable population levels. This includes ensuring that incidental takes do not exceed a stock's potential biological removal level.
- Develop conservation and recovery plans that contain site-specific management measures with objective, measurable criteria to recover ESA-listed species and depleted marine mammal stocks.
- Monitor population status.
- Create measures to recover threatened or endangered species.

(4) *Conserve Biodiversity*

- Develop and implement measures to conserve non-target species.
- Ensure that no native species shall go extinct due to anthropogenic factors.
- Monitor and evaluate impacts of invasive species on native species.
- Establish conservation and management measures to reduce fishing mortality of non-target species (e.g., minimize bycatch and discarding), and establish bycatch thresholds that will sustain non-target species.
- Monitor the status of non-target species that are significantly impacted by anthropogenic activities.

- Establish measures to conserve species diversity where an observed and sustained decline in species diversity (e.g., mean species richness from fisheries independent surveys) is below the range of observed natural variability.

(5) *Conserve Genetic Diversity and Structure*

- Define Evolutionary Significant Units (ESUs) for threatened, endangered or overfished species.
- Develop and implement harvest policies that protect genetic diversity of species or stocks by protecting ESUs from excessive mortality.
- Monitor ESU status for local spawning aggregations.
- Establish measures for those species or stocks at risk of losing genetic diversity to protect the ESU.

(6) *Conserve Living Marine Resource Habitat*

- Develop and implement measures to conserve Essential Fish Habitat and Critical Habitat for all targeted and protected species with respect to their ability to spawn, breed, feed and/or grow to maturity.
- Evaluate habitat designations.
- Evaluate potential adverse effects of fishing on habitat and minimize adverse effects of fishing on habitat.
- Minimize adverse perturbations (from both fishing and other user sectors) to be less than the range of natural disturbances for the appropriate physical and geological processes that operate in ecosystems.
- Establish measures to conserve those habitats that are negatively impacted.

(7) *Maintain Trophic Structure*

- Develop and implement measures to minimize anthropogenic impacts on trophic structure and functioning. Ecological relationships between harvested, dependent and related species shall be maintained within the range of observed natural variability.
- Develop and implement measures to take the trophic role of species into account when establishing harvest levels, including the effects of the combined removal of all targeted species on the ecosystem.
- Monitor trophic relationships among targeted species, their predators, and their prey.
- Establish measures to restore the fundamental ecological relationships in those food webs that have human-induced deterioration of trophic structure.
- Develop and implement harvest policies that sustain adequate forage base, in situations where fisheries potentially compete with top trophic level consumers (e.g., marine mammals, turtles, sea birds, or similar protected species) for shared resources (e.g., forage fish such as small pelagics), to ensure that sufficient quantities of the shared resource are available to sustain the top trophic level consumers at their population thresholds.

(8) *Prevent Systemic Over-exploitation*

- Prevent systemic over-exploitation of an ecosystem at relevant spatial and temporal scales, cognizant of items 1-7 above as appropriate. This may require development and implementation of a limit for the total combined removal of all targeted species or some equivalent means. It provides a buffer for uncertainty such that the total removal cap is established as less than the combined total of all targeted and non-target removals.
- Allocate tradeoffs in harvestable biomass among all targeted species subject to the constraint of the total removal cap, up to but not exceeding the total cap.
- Establish measures and policies to avoid exceeding the systemic cap and to reduce total system-wide exploitation if it is exceeded.

(9) *Improve knowledge of natural and anthropogenic processes controlling ecosystem structure and function to enable more accurate forecasts of living marine resources*

- Monitor the status of non-target species that are significantly impacted by anthropogenic activities.
- Monitor trophic relationships among targeted species, their predators, and their prey.
- Monitor population status of protected species and marine mammals at specific levels of assessment quality every X years.
- Monitor the status of species or species complexes relative to overfishing and overfished reference point at specific levels of assessment quality every X years.
- Improve our understanding of the importance of bottom-up forcing in determining episodic recruitment events in target species and the prey of target species.

Appendix C. Basic approach to management of fisheries in federal waters, with an emphasis on management of groundfish in the Bering Sea and Gulf of Alaska.

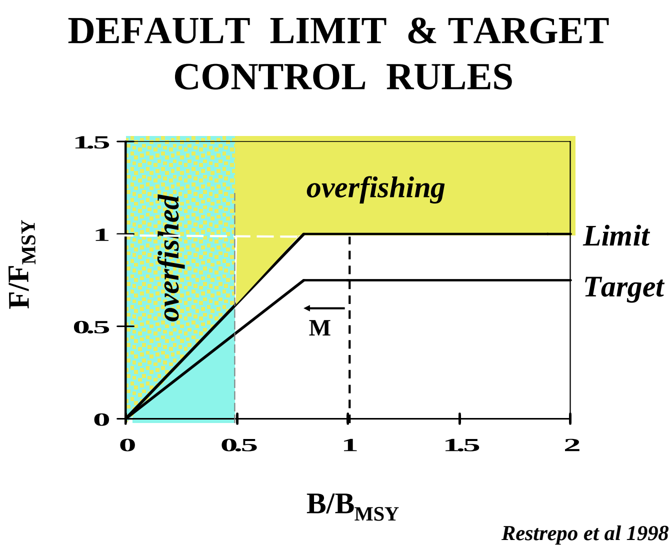
Several elements of the fisheries management system adopted by NOAA conform to the goals of EAM. Several Regional Councils and their associated Regional Offices have adopted harvest strategies that are designed to prevent overfishing, rebuild protected species, preserve biodiversity, protect habitat and encourage public participation in decision making. This system evolved over time in an effort to comply with the requirements of the various laws governing fisheries management including the National Environmental Policy Act (NEPA), the Magnusson Stevens Fisheries Conservation and Management Act (MSFCMA), the Endangered Species Act (ESA). The groundfish management system recommended by the North Pacific Fisheries Management Council (NPFMC) and implemented by NOAA Fisheries is a good example of an FMP that has successfully integrated the goals of EAM into its management strategy.

Overview of National Guidelines for Fisheries Management.

NOAA Fisheries established guidelines for Fishery Management Plans (FMPs) to ensure that the catch of federally managed species is consistent with the goals of building sustainable fisheries. Overfishing is defined as any amount of fishing in excess of the limit fishing mortality level (Flim). The fishing mortality rate (Fmsy) that would produce the maximum long-term average catch (Maximum Sustainable Yield, MSY) is the upper bound for Flim. The long-term expected level of biomass (stock abundance) that would result from fishing at Fmsy is defined as the MSY stock size (Bmsy), recognizing that natural fluctuations above and below the MSY stock size are normal.

NMFS guidelines pertaining to National Standard 1 instruct managers to implement harvest strategies that maintain stock sizes at or above their MSY stock size on average. When stock sizes decline to a level where there is significantly increased concern regarding potential impairment of stock productivity, delayed rebuilding to Bmsy, or potential ecosystem harm, the stock is considered to be depleted (Fig. 1). When a stock reaches this level rebuilding plans must be developed and implemented to improve stock condition.

Fig. 1. Summary of thresholds used in managing commercial fisheries in federal waters.



Each Council and associated Regional Office of NOAA Fisheries is responsible for defining MSY control rules. These rules generally guide managers to set target fishing mortality levels below the limits to avoid exceeding the Flim and to account, to the extent possible, for social, economic, and ecological factors.

NMFS is also responsible for enforcing its harvest policies. Ideally, catch and bycatch should be directly monitored with an in-season catch reporting system that provides accurate estimates of catch of both target and non-target species. In many regions NOAA Fisheries supports fishery monitoring programs that consist of at-sea and/or shoreside observers. These monitoring programs allow managers to assess the amount of catch of target species and incidental species in real time. Fisheries can be closed to protect a species from reaching the OFL. In regions where time-area or gear restrictions are utilized to control catch, scientists conduct research to verify that these management tools provide sufficient control to keep fishing mortality at or below Flim.

NOAA Fisheries is also responsible for conducting stock assessment surveys, which provide relative biomass estimates of many target species, non-target species, and indicator species. LMRs are typically monitored through periodic surveys. These surveys represent a major contribution to the goal of conserving biodiversity because they provide a historical record of distribution and abundance.

Overview of Alaskan Groundfish Management

The management system used in the Alaska groundfish fisheries serves as an illustration of how the MSFCMA, ESA, and NEPA guide managers toward an ecosystem approach to management. In an effort to prevent overfishing and to comply with the provisions of the MSFCMA, the North Pacific Fishery Management Council (NPFMC) working in association with the Alaska Regional Office has developed a system of in-season constraints on target groundfish species, non-target groundfish species (primarily groundfish incidentally captured), forage species, and prohibited species (important non-groundfish species incidentally captured). The catch constraints are built around a tier system for estimating ABC and OFL for stocks or stock complexes. The tier system provides guidance on the maximum permissible levels of catch given the quality of information available (see Goodman et al. 2002 for a review of harvest strategy employed in the North Pacific groundfish fishery). In addition to the constraints on catch at the species or species group level, the NPFMC also imposes an overall cap on the total amount of groundfish that can be removed (Witherell 2005). In the Bering Sea Aleutian Islands region this overall constraint results in considerable reductions in catch for several target species.

The establishment of Total Allowable Catches (TACs) is fundamental to the management of Alaskan groundfish fisheries in federal waters. It involves annual evaluation of the best available scientific information through review of documents and public meetings. The first step begins with the preparation of Stock Assessment and Fishery Evaluation (SAFE) reports. These reports contain analyses summarizing the information about the individual stocks and groups, and include Acceptable Biological Catch (ABC) and overfishing levels (OFL) recommendations for future years. The authors of these reports (generally NOAA Fisheries scientists) present their findings to NPFMC and its Groundfish Plan Teams and Scientific and Statistical Committee (SSC) for further review. After scientific review and public discussion, the NPFMC recommends TAC levels for the upcoming year, which have to be approved and subsequently implemented by NOAA Fisheries. Alaska groundfish managers always set TAC $\leq$ ABC < OFL. Catch is usually less than TAC, almost always less than ABC and is always less than OFL. Agency scientists are currently working on the development of objective rules for incorporating uncertainty in estimated stock biomass, catch rates, stock structure, and productivity. These rules, as noted earlier in this paper, must balance the risk of populations becoming depleted with the benefit to society of resource utilization.

The NPFMC’s groundfish management strategy is designed to preserve biodiversity by protecting target species along with non-target species that are impacted by the fisheries. The FMPs identify four groups of species: prohibited species, target species, other species and forage fish. The North Pacific Fisheries Management Council (NPFMC) is currently reviewing these categories in an effort to comply with proposed revisions to the guidelines for National Standard 1. Anticipated changes include a split of the “other species” complex into species assemblages that share common life history characteristics. AFSC scientists produce annual or biennial SAFE reports that document the status and trends of target and non-target species (e.g. other rockfish, other flatfish and other species) and provide ABC recommendations for both target and non-target species.

The NPFMC’s groundfish FMPs also include constraints stemming from the Endangered Species Act. Managers imposed time, area, and gear restrictions on groundfish to reduce direct and indirect mortality of Pacific salmon, short-tailed albatross, and Steller sea lions. These constraints, coupled with deterrents to the development of directed fisheries for forage species, act to mitigate adverse impacts of fishing on endangered species. A biomass control rule was established for pollock, Pacific cod and Atka mackerel to preserve the forage base for Steller sea lions.

The NPFMC groundfish FMPs have recently been reviewed with respect to protection of essential fish habitat. In Alaska, large areas are protected from effects of fishing through seasonal or year-round closures (Witherell 2005). The review of EFH found that current levels of harvest are not producing a measurable impact on the reproduction, growth, or distribution of managed species in Alaska. Despite this finding, the NPFMC recommended preemptive measures to protect habitats of particular concern and deep water corals.

The practices of the NPFMC and Alaska Regional Office (ARO) also comply with the goals of seeking public input on management decisions. The NPFMC and ARO recently completed a programmatic environmental impact statement on groundfish fisheries management in Alaska. Alternatives reviewed in this document were identified through public meetings. The document provided a clear assessment of the trade-offs between management alternatives and the expected environmental impacts associated with each alternative. This process illustrates that compliance with the provisions of the NEPA contributes towards the goal of seeking and incorporating public input into decision making.

In conclusion, this brief review of management of Alaskan groundfish illustrates that managers are taking incremental steps towards implementing ecosystem approaches to management. The review also illustrates that, when these steps are taken, fisheries can be managed in a sustainable manner while providing economic benefits to the nation.

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Ecosystem White Paper #3

Freshwater Issues

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Description of the Issue:

Freshwater is our most precious and finite natural resource -- The total amount of freshwater in lakes, streams, rivers and groundwater accounts for less than one percent of water on the Earth. As human populations increase, so does competition for water to meet societal needs while maintaining needs of the earth's biological systems. Additionally, there are increasing demands for recreational use of water in streams, river and lakes, and increasing awareness of interacting hydrological, ecological and social systems required for a healthy environment, dynamic economy and equitable allocation and use of freshwater.

By the year 2020, the human population in the United States will exceed 335 million, with the majority living in coastal counties that account for only 17 percent of the U.S. land area (excluding Alaska). Increasing population density, coupled with faster-growing economies in coastal areas, will require resource management policies that are built upon a holistic approach to managing ecological goods and services, while at the same time accounting for human demands on water resources (Palmer et al. 2004). This will, for example, increase the effects of drought on economic, social and ecological systems, including delivery of freshwater to the coastal ocean and estuaries (WGA 2004). A consequence will be the need for an improved drought forecasting capability developed at the appropriate spatial scale. Increasing populations also bring increased biological threats and the need to better forecast and mitigate their effects. For example, aquatic invasive species are a global problem that threatens sectors of the US economy by changing and reducing the beneficial societal uses of its coastal ecosystems. The pathways by which invasive species reach U.S. coastal ecosystems all involve human activities, especially those that relate to commerce and trade. Aquatic invasive species can have dramatic effects on ecosystems; altering trophic structure, productivity and increasing risk of extinction of native species. Annual costs to the U.S. economy have reached hundreds of millions of dollars per year and are increasing. While the impact of invasive species is not unique to freshwater ecosystems and affects all coastal ecosystems, the Great Lakes is a "hot spot" for invasive species introductions to major interior sections of the U.S. and Canada, having 162 documented introductions representing fishes, invertebrates, aquatic plants, algae, and pathogens.

According to the Council of State Government's report entitled "Water Wars" (CSG, 2003):

> "*Water, which used to be considered a ubiquitous resource, is now scarce in some parts of the country and not just in the West as one might assume. The water wars have spread to the Midwest, East and South as well." Water "…conflicts are occurring within states, between states and the federal government and among environmentalists and state and federal agencies." Tribal governments "… are pursuing several legal battles to reclaim their water rights.*"

The report of the National Science and Technology Council's Subcommittee on Water Availability and Quality (NSTC, 2004) explains that:

"*Without quantifiable and scientifically defensible estimates of environmental water requirements, water gridlock–intense competition among irrigation, navigation, municipal supply, energy, and the environment–is unlikely to be resolved*".

In 2000, the total amount of withdrawals (not necessarily consumption), including saline water, in the United States approached 400 billion gallons per day (Hutson et al. 2004). Nearly 40% of this amount was used in thermo-electric power generation and about one-third for irrigation and agriculture use (Figure 1). Domestic use accounted for only one percent; the remaining amount was to meet industrial and public water supply needs. It is anticipated that future increases in consumptive use, energy production, and irrigation will accentuate the challenge of achieving an equitable balance between ecosystem conservation and the economic vitality of watersheds and estuaries.

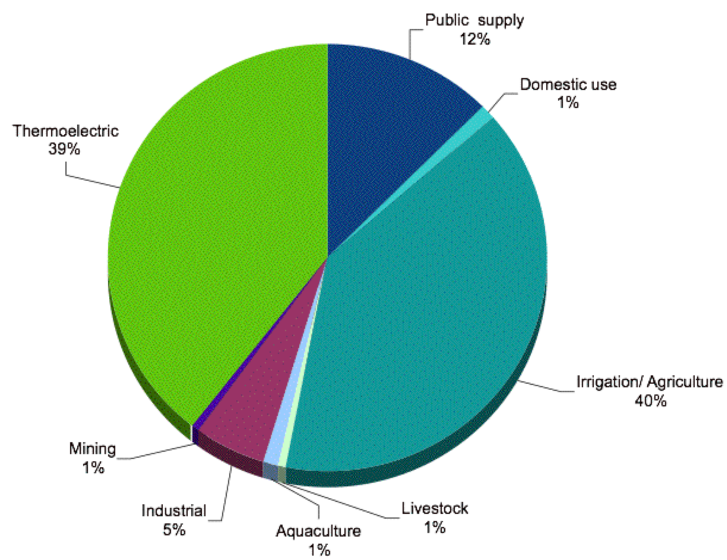

Figure 1. Freshwater use in the US in 2000 as a percentage of total freshwater (surface and groundwater) withdrawl (345.6 billion gals per day) (Hutson et al. 2004).

These environmental and societal drivers shape the fundamental challenges for NOAA in the next 15 years. The primary challenges for NOAA are:

1. Framing the tradeoffs decision makers will face in balancing the conservation of freshwater and coastal ecosystems with demands for safe drinking water, crop irrigation, recreation, and flood control;
2. Forecasting climate change and climate variability effects upon the freshwater-coastal ecosystem and availability of water for human uses

3. Breaking down the persistent view that there are two separate ecosystems (freshwater and coastal), and advancing a new understanding of the critical coupling of resource pathways and food webs between the two environments;
4. Understanding the linkage between water quality and quantity and public health and developing models and forecasts to aid in reducing human health risks in freshwater and coastal ecosystems; and
5. Delivering relevant science and information for effective decision making.

NOAA and its partners must rise to these challenges on both national and international scales if the nation is to maintain functioning freshwater, estuarine and coastal ecosystems that support biodiversity and sustainable resource use, promote prosperous coastal communities and minimize human health risks.

II. Science Capabilities Necessary to Support Future Decision Making

The recommendations of the National Council for Science and the Environment (Schiffries and Brewster 2004) on water sustainability and security underlined fundamentally new approaches for balancing societal water needs with those of the Earth's ecosystems while assuring sustainability. Specific recommendations that NOAA's mission supports through its science include:

- Water management based on hydrological and ecological linkages (rather than political boundaries) and equitable allocation for people and ecosystems;
- A robust set of indicators for sustainable water management,
- Advancing inter-disciplinary scientific research,
- Closing the gaps between water science and water policy,
- Developing a broad spectrum of capabilities to assure water quality, sanitation and security, and
- Improving education and outreach.

In addition, the General Accounting Office has noted that the US lacks a national system that assembles key information on economic, environmental and social and cultural issues (GAO 2004). Support for effective decision making on freshwater issues will require an integration of economic, environmental and social/cultural issues around each of the recommendations made by the National Council for Science and the Environment (Schiffries and Brewster, 2004), highlighting the critical need to meld physical and biological sciences with social and economic sciences if NOAA's ecosystem science is to effectively support regional decision making.

Future water resource conflicts will be intense in freshwater systems. It is therefore critical that NOAA's science products help decision makers understand fundamental tradeoffs between human needs for water and environmental services provided by fresh water in rivers and estuaries. Resolving these fundamental tensions will require that NOAA develop a sound scientific understanding of watersheds and coastal regions as a single ecosystem, and deliver science products that inform decisions regarding allocations of a diminishing resource. Developing valuation systems (e.g., the cost effectiveness of water recovery systems versus the ecological consequences of extracting larger amounts of freshwater for agriculture, power generation and industrial purposes) to assist in evaluating tradeoffs is equally important. NOAA must also deliver timely scientific information in support of major decisions regarding climate variability and change, and protection of freshwater-dependent ecosystems from the harmful effects of pollution and habitat alteration arising from coastal development. Prototypes of such approaches already exist (Kimmerer 2000; Powell et al. 2002). The development of multi-scale socio-ecological models will be essential for informing policy and management decisions by providing a wider range of alternatives for achieving resource sustainability and accounting for variability at different temporal scales (Costanza et al. 2002).

Understanding and reducing human health risks from degradation of fresh water and marine ecosystems is a major challenge facing our nation. NOAA’s Oceans and Human Health initiative has recently begun to investigate how ecosystem conditions in the oceans and Great Lakes affect human health and well being, and strengthening these capabilities will improve our ability to respond to this challenge. Research, monitoring, modeling, forecasting, and education are all key elements used by NOAA in such integrated science programs. NOAA has strong capabilities in ecosystem modeling and in integrated sustained observation programs for coastal ecosystems, which will enable stronger support of a wide range of activities and improve ecological forecasts. These integrated science capabilities allow NOAA to help guide a wide range of ecosystem restoration and species recovery efforts that explicitly include humans as part of the ecosystem (e.g., South Florida, Pacific salmon), and also to develop the NOAA National Center for Research on Aquatic Invasive Species. This new center provides communication and coordination for the Agency’s research investments in support of understanding, preventing, responding to and managing AIS invasions in the U.S. coastal ecosystems.

Meeting the Challenge – NOAA Science Priorities

To help meet the nation’s future freshwater ecosystem challenges, NOAA will need to collect and deliver accurate ecosystem-level information to managers. This will require a shift from traditional small-scale research and piece-meal management schemes to large-scale, holistic frameworks for both science and policy. The task must be to predict the ecosystem and societal consequences of alternative management strategies, and provide these predictions to decision makers in a timely and transparent fashion. Thus, NOAA must be prepared to play a key scientific role in evaluating ecosystem responses to alternative ecosystem management plans, many of which will be locally-developed “bottom up” initiatives encompassing diverse economic and environmental interests.

NOAA’s research priority in meeting one of the Nation’s biggest challenges – the looming conflict between ecosystem conservation and increasing human use of water resources – will be to develop advanced models that accurately forecast water supplies, as well as a new suite of hydrologic models that describe how freshwater environmental attributes will shift with climate change and land uses. The use of high-resolution (i.e., 1 km spatial resolution) distributed hydrologic models has not been practical in operational forecasting until fairly recently. It is now feasible to develop and implement high-resolution rainfall-runoff models due to the advent of high-quality spatial data, the ability to process that data using geographic information systems, and the improvement in the spatial estimation of precipitation as a result of the NEXRAD network. As part of the calculations necessary to produce streamflow forecasts, these models have the capability to obtain estimates of information such as soil moisture, snow water equivalent, soil temperature, and other ecosystem habitat parameters, at the same high resolution. These new forecasts will inform the decision making process for agriculture, water, and ecosystem managers alike.

NOAA is leading the way in implementation of those greatly enhanced services by placing at the core of its Water Resources Initiative the proposed Community Hydrologic Prediction System (CHPS). CHPS will allow the coupling of different models, improve forecasts and expedite the research-to-operations timeline. These goals will be achieved by developing models directly in the same environment used in National Weather Service river forecast operations. CHPS will include the ability to couple models operating at disparate temporal and spatial resolutions, such as groundwater models and surface hydrology models. CHPS will build on standard sets of tools and protocols, and open data modeling standards. It will support data assimilation, high-resolution distributed forecasts, including uncertainty estimates, data assimilation, and the operational implementation of advanced water quantity and quality forecast models not currently available. CHPS open architecture will encourage partnerships with other Federal and non-Federal organizations.

Understanding and predicting how shifting climate regimes will affect water supplies and the freshwater-coastal ecosystem is NOAA’s second major science priority. Climate cycles have strong influences on annual stream flows, freshwater ecosystem structure and function, and abundance of important aquatic species (Kiffney et al. 2002, Greene et al. 2005). Long-term climate change is likely to alter flow regimes in ways that will adversely affect water availability for both human consumption and the recovery of important species (Mote et al. 2003, Beechie et al. 2006). NOAA will need increased capabilities for forecasting how such climate changes will affect flood or drought intensities, productivity of freshwater or coastal ecosystems, drinking water, and recreational and shellfish beaches. NOAA must also be able to predict where the ecological effects of decadal scale wet or dry regimes will be most dramatic, and provide scientific information on the ecological consequences of different freshwater management approaches to meet the human demands for freshwater.

Just as important as the development of new models is the procurement of data required to drive those models, and new uses of those observations. In collaboration with NASA, NOAA will be exploring the use of space-based observations to improve potential evapotranspiration estimates, and to assimilate snow water equivalent and soil moisture observations into the new high-resolution hydrologic models. It is estimated that the use of new observations, in coordination with better estimates from dual-polarization radars and enhanced automated surface observation stations, will greatly improve the skill in short- and long-term forecasts of streamflows, in ranges from droughts to floods. NOAA is gaining the resources that will also increase the amount, type and accuracy of water resource information available to NOAA and its external customers. The integration efforts of the Water Resources Initiative will make use of the efforts of the National Integrated Drought Information System (NIDIS), NOAA's Environmental Real-time Observation Network (NERON), the National Water Quality Monitoring Network, and the emerging Integrated Ocean Observing System.

NOAA's third science priority is the development of new ecosystem response models that allow us to predict how resource decisions will impact the delivery of ecosystem goods and services, including abundance of commercial and recreational aquatic species. Breaking down the persistent view that freshwater and coastal ecosystems are separate, and developing a new understanding of integrated ecosystems will be needed to better characterize the consequences of water management decisions. Freshwater and marine environments are tightly coupled by delivery of sediments, contaminants, and nutrients from watersheds to estuaries and coastlines, as well as migrations of anadromous and catadromous species between marine and freshwater habitats. NOAA will require a greater capacity to predict the ecosystem consequences of human actions such as reduction of sediment supply by reservoir construction/operation and its effect on coastal erosion, increased delivery of pollutants to the freshwater-coastal ecosystem, and altered nutrient fluxes between freshwater and coastal environments. In turn, this will require much improved scientific understanding of the complex linkages between freshwater and coastal food webs at different spatial scales and temporal resolutions. Biomass fluxes between freshwater and coastal environments (mainly anadromous fishes such as striped bass, American shad, sturgeon, and Pacific and Atlantic salmon) are critical pathways by which food resources and nutrients are transferred between freshwater and saltwater food webs, and models that help predict how changes in abundance of these species impact the freshwater-coastal ecosystems are sorely needed. Likewise, for species that make transitions between freshwater and marine systems, models that accurately represent the drivers of these populations will require integration of freshwater and marine processes (Greene et al. 2005). NOAA must also improve its capabilities in understanding and modeling critical drivers on species and food webs, including water quantity and quality changes, non-native species introductions, fishing, altering physical processes, and other human impacts.

The fourth NOAA science priority is to provide managers with a better understanding of the human health consequences of freshwater and coastal ecosystem degradation. A variety of contaminants can adversely impact drinking water, recreational waters, and fish and shellfish leading to illness (e.g., Health Canada, 1995). Chemical contaminants come from both point and non-point sources with urban/suburban runoff and atmospheric deposition increasingly being major sources. Microbial contaminants such as viruses and bacteria can come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife, and enter drinking water after major storm events (Whitman and Nevers 2003). Another threat is harmful algal blooms. For example, bloom-forming, toxic cyanobacteria occur worldwide in nutrient-enriched freshwaters and are noted causative agents for human and animal illness/mortality. Harmful algal blooms can have disastrous short- and long-term consequences for water quality and resource utilization (e.g., Paerl & Millie 1996). While contamination of drinking water is a major concern, chemical contaminants, microbial contamination and harmful algal blooms also pose public health concerns through contact with contaminated water during recreation (Health Canada 1998, WHO 1998) and contamination of recreational and commercial fish and shellfish.

In meeting this need NOAA has a significant role in research and its application at the intersection of meteorology, biological oceanography, hydrology, microbiology, toxicology, and watershed and coastal processes in relation to identifying and reducing human health risks. This will require NOAA to increase its multidisciplinary approach to understand and forecast coastal-related human health impacts for public health and natural resource policy and decision making. Predictive models and monitoring networks will need to be reconfigured to provide data and information products relevant to water quality impacts on human health. The NOAA Center of Excellence for Great Lakes and Human Health (Brandt et al. 2004) is a multi-disciplinary research effort focusing on understanding the inter-relationships between the Great Lakes ecosystem, water quality and human health. There are also Centers taking a similar approach but focusing on the watershed – coastal marine intersection, including the proposed Gulf of Mexico Cooperative Institute. All Centers have a scientific focus on ecosystem forecasting to minimize risks to human health in coastal environments.

NOAA will also need to expand its science-based ecosystem approach to restoring habitat structure and function to ensure that drinking water that flows through watersheds and into the Great Lakes and marine coastal areas do not present a risk to human health. This need is exemplified in the Great Lakes because its coastal waters are potable. There are 121 watersheds that feed into the Great Lakes with approximately 44 million people living in the Great Lakes basin (20 million reside in the US) and depending on the Great Lakes for drinking water. The NOAA Great Lakes Habitat Restoration Program, once in place, is an example of one program that will address habitat loss and degradation, which are national issues that span the entire Great Lakes basin as well as other coastal areas. Strong partnerships and sharing expertise, knowledge and resources are the key to effective restoration and protection.

Finally, NOAA's science must be translated in transparent ways for use by managers and decision makers or it will not yield its full benefit to society. NOAA will need to develop more efficient mechanisms for delivery of scientific information to managers and policy makers. Regional ecosystem management plans will likely be large and complex, describing strategies and actions aimed at improving the functioning of an ecosystem. Implementation of these plans, however, is partly affected through many institutions that govern and influence human activity. Most of these institutions have jurisdiction over only a part of the affected ecosystem, are limited to a particular geographic sub-region or to a subset of the ecosystem's functions, or both. To the extent that the ecosystem components are interconnected, so to must be the laws and regulations that institutions enact and implement. The key is that the stronger the connections among the ecosystem's components, the stronger must be the connections among the institutions. Moreover, socioeconomic factors such as population growth, economic development, and land use can be influenced by laws and regulation, but not fully determined by these formal governance mechanisms. Instead, these factors are the aggregation of many small, individual decisions. NOAA must improve its understanding of the dynamics of these economic and social spheres in order to develop more efficient methods of delivering relevant scientific information. This drives the need to interweave social and economic models with the physical, biological and ecosystem models.

Better monitoring is at the core of an effective ecosystem approach to management, and better synthesis of data will be essential to effective decision support for freshwater management issues. The stakes are high in meeting the human needs for freshwater while sustaining ecosystem goods and services. The need for development of regional coastal observing systems has been highlighted recently by a number of studies as well as by the NOAA Strategic Plan, the National Oceanographic Partnership Program, and the Integrated Ocean Observing System (IOOS). Continual assessment of the status and trends in watershed and coastal environments permits identification of perturbations that may signal changes in the ecosystem, puts current trends into an historical framework, allows us to differentiate true environmental change from variance and provides a context to assess the impact of predicted changes. The development of a coastal component of IOOS is a fundamental need in our coastal, marine and Great Lakes regions.

III. Partnerships Necessary to Effectively Address the Emerging Issues

Largely due to jurisdictional boundaries, agency mandates, and nascent scientific strategies to support integrated management, the overall goal to balance the multiple demands of the limited freshwater resources of the Nation (or specific coastal watersheds) has remained elusive.

First and foremost, NOAA must act to provide leadership for developing a holistic response to freshwater issue for 2020 and beyond. Meeting these enormous challenges will require partnerships with academia, the private sector, other federal agencies and international institutions to bring to the fore: 1) the necessary technology that leads to more environmentally sound use, allocation and conservation of freshwater; 2) developing ecological indicators and forecasts at multiple scales and 3) improved understanding of the interactions among the atmosphere, biosphere and hydrosphere as they affect the coupled marine/Great Lakes and watershed ecosystems.

This will also require fostering stronger partnerships with institutions that have inland, coastal and atmospheric mandates such as; US Departments of Agriculture, Interior and Defense, the Environmental Protection Agency, Geological Survey, and NASA. NOAA should also strengthen scientific cooperation and information exchange with the international community, because without such international linkages NOAA cannot cut across political and jurisdictional boundaries. The importance of such linkages is exemplified in the Great Lakes where joint management with Canada is essential. The International Joint Commission (a commission jointly appointed by the President of the United States and the Premier of Canada) works to bring together international federal, state, local, private and tribal entities to focus on specific issues. In addition, NOAA will need to establish closer and more effective partnerships with the Shared Strategy in Puget Sound, CalFed Bay-Delta Program, river basin commissions such as the Delaware River Basin Commission, the Susquehanna River Basin Commission, and the Florida River Management Districts, and county and local emergency managers. This will further help facilitate participation by local entities and stakeholders to address specific issues and reach mutually acceptable management options.

IV. Benefits to NOAA, Constituents, and Society in General from this Effort

There is no resource more precious or finite than freshwater. Science-based ecological frameworks using “next generation” hydrologic and ecosystem models and forecasts are needed to inform local, state and federal decision-makers as they set goals and targets for adequate and reliable supplies of freshwater while meeting goals for ecosystem goods and services. The need and urgency for such a course of action have been articulated for many years, most recently by the National Science and Technology Council (NSTC 2004), Government Accountability Office (GAO 2004), the National Research Council (NRC 2004), and the National Council of Science and the Environment (Schiffries and Brewster 2004). The societal benefits accrued from NOAA’s ecosystem science in this area are:

a. Providing scientific data and expert counsel prior to any changes in the water budgets that may pose adverse environmental or social consequences;
b. Forecasting the amounts and timeliness of stream flow for human activities and sustaining production of ecosystem goods and services; and
c. Providing scientific information and management support on the supply and quality of water to protect, restore and enhance aquatic ecosystems and human health.

NOAA’s water resources information should support the full range of stakeholders (e.g., farmers, utilities, water managers, land managers, wild life managers, business owners and decision makers) with the science needed to make informed decisions on their operations, and allow them to plan for, rather than react to, the inevitable changes from shifting climate regimes (e.g., decadal scale changes from “wet” to “dry” periods). The freshwater allocation issue allows NOAA, working with partners, to help illustrate that protecting functioning ecosystems and conserving aquatic species will provide the natural services that benefits, rather then competes with, robust human societies.

The following are priorities for science to support an ecosystem approach to freshwater management:

- Develop next-generation models to forecast ecosystem scale changes in water budgets in response to human demand and climate and land use change at annual and decadal scales. These models also need to inform selection of alternative management strategies.

- Establish and facilitate integrated monitoring programs that provide a continuum of observations from the headwaters of watersheds through the coastal ocean to provide a holistic understanding of hydrologic cycles and biological status, trends and interactions.

- Improve understanding, technologies and forecasts that minimize public health risks from consumptive use and contact recreation in coastal systems.

- Increase environmental literacy of the relation of climate and land use to freshwater supply and quality; as well as the tight biologic and hydrologic coupling between watersheds, estuarine drainage areas and adjacent coastal waters.

This can only be accomplished through partnerships based on an ecosystem approach to both science and management. A regionally based, nested ecosystem framework with a shared strategy to management will be needed. This shared strategy must acknowledge jurisdictions and management mandates but provide a forum for collective decision making. This will require that observations and research are also done with a greater degree of collaboration and are guided by and responsive to shared management needs, while still providing the science to meet the management or regulatory needs of the parent agencies. Ecosystem based agreements assuring transparent data sharing and management will be essential to facilitate the necessary collaboration, as well as to provide information on the scale needed to inform shared decision making. This is not just a theoretical construct but has been initiated and put into action (e.g., with regard to South Florida Ecosystem Restoration under the aegis of federal-state-tribal task force established in federal law, and the Shared Strategy in Puget Sound, a voluntary, collaborative effort to recover Endangered Species Act listed Chinook salmon).

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Mandates:

- Clean Water Act: Research and related programs for restoration of estuarine habitats in the Great Lakes. 33 USC § 1268
- Coastal Zone Management Act, 16 USC § 1451 *et seq.*
- Establishment of Great Lakes Research Office, 33 USC § 1268 (d)
- Establishment of the National Estuarine Research Reserve System, 16 USC § 1461
- Estuary Restoration Act, 33 USC § 2901-2909
- Fish and Wildlife Conservation Act, 18 USC § 2901-2911
- Global Change Research Act, 15 USC § 2921-2961
- Harmful Algal Bloom and Hypoxia Research and Control Act, 16 USC § 1451
- Marine Migratory Gamefish Act, 16 USC § 760 (e)
- National Aquaculture Act, 16 USC § 2801-2810
- National Climate Program Act, 15 USC § 2901-2908
- National Coastal Monitoring Act, 33 USC § 2801-2805
- National Contaminated Sediment Assessment and Management Act, 33 USC § 1271

- National Environmental Policy Act, 42 USC § 4321-4347
- National Marine Sanctuaries Act, 16 USC § 1431 *et seq.*
- Nonindigenous Aquatic Nuisance Prevention and Control Act, and National Invasive Species Act, 16 USC § 1431-1445
- Oceans and Human Health Ac, 33 USC § 3101-3104
- Regional Marine Research Programs, 16 USC § 1447 (b)
- The Endangered Species Act, 16 USC § 1531-1543
- The Estuary (Estuarine) Protection Act, 16 USC § 1221-1226
- Water Resources Development Act: Great Lakes habitat remediation, 33 USC § 2326 (b)
- Water Resources Development Act (WRDA), 33 USC § 2572

Ecosystem White Paper #4

Marine Zoning and Coastal Zone Management

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I. Description of the Issue

Background

Coastal areas and nearshore waters are subject to an array of human activities with steadily growing impacts on our natural ecosystems. While coastal watershed counties comprise less than 25 percent of the land area in the United States, they are home to more than 52 percent of the total U.S. population (USCOP, 2004). With increasing population and development pressure, coastal managers are faced with a need to manage competing demands for coastal and marine resources, minimizing the impacts of development and other uses on the coastal and marine environment, and conserving coastal and marine ecosystems. In addition, a growing number of activities are taking place or proposed in federal waters from three to 200 miles offshore and international waters beyond the Exclusive Economic Zone (EEZ).

Over the coming decades, the use of coastal and marine ecosystems will increase. Coastal land will continue to be in high demand for development, ports, and recreation. In addition, in marine ecosystems on the shelf, activities such as fishing, energy generation, mineral extraction, aquaculture, waste disposal, transportation, tourism, recreation and other uses will compete for space.

The U.S. Commission on Ocean Policy envisions a desirable future for the oceans and Great Lakes and is a worthy goal for NOAA:

> *In this future, the oceans, coasts and Great Lakes are clean, safe, prospering, and sustainably managed. They contribute significantly to the economy, supporting multiple beneficial uses such as food production, development of energy and mineral resources, recreation and tourism, transportation of goods and people, and the discovery of novel medicines, while preserving a high level of biodiversity and a wide range of critical natural habitats.*

> *In this future, the coasts are attractive places to live, work and play, with clean water and beaches, easy public access, sustainable and strong economies, safe bustling harbors and ports, adequate roads and services, and special protection for sensitive habitats and threatened species. Beach closings, toxic algal blooms, proliferation of invasive species, and vanishing native species are rare. Better land-use planning and improved predictions of severe weather and other natural hazards save lives and money.*

To achieve this vision, our busy seas and coasts will demand governance solutions to manage an intensifying and increasingly conflicting set of activities. With few exceptions, such as Oregon's ocean policy or state interests on offshore impacts on coastal zone resources, the past 30 years of coastal zone management (CZM) generally have seen the vast majority of states and territories focusing on the "dry side" rather than the "wet side" of the land and water margin. This is no longer the case. Already, states such as Massachusetts and California are exploring the potential of marine zoning as a tool to separate conflicting uses, achieve conservation and economic objectives, and enhance safety. The Pew Commission also advocates marine zoning to improve marine resource conservation, actively plan ocean use, and reduce user conflicts (Pew Ocean Commission, 2003).

Similar to zoning on land, marine zoning designates geographic areas for specific uses, such as transportation, conservation, non-consumptive uses, energy development or fishing. Zoning is a way of reducing user conflicts by separating incompatible activities and allocating or distributing uses based on a determination of an area's suitability for those uses, in relation to specific planning goals (Courtney and Wiggen, 2003). Ideally, zoning has numerous components including a map that depicts the zones and a set of regulations or standards applicable to each type of zone created (Courtney and Wiggen, 2003), as well as plans for implementation, monitoring, and enforcement. Zoning also is a tool for resource management, conservation and restoration.

Courtney and Wiggen (2003), in their paper on ocean zoning in the Gulf of Maine, note that "ocean zoning is… complex in that it needs to address and manage activities on the ocean surface, in the airspace above, throughout the water column, and on and beneath the seabed. It is conceivable that one area of the ocean could support multiple uses (by different sectors) or several management objectives simultaneously and it is also possible that one use or management objective would preclude all others. Ocean zoning may also have a temporal dimension."

Like other ocean management tools, ocean zoning often involves tradeoffs between competing uses. These conflicts may be more explicit within a zoning scheme as uses and use prohibitions are spatially delineated. However, zoning also offers an opportunity to better assess the tradeoffs associated with different management actions. Assessing the social and economic costs and benefits of different management options within a zoning framework allows managers to look not only at who gains and loses, but where those gains and losses are likely to occur and to better predict unintended consequences and their impacts.

For example, many commercial and recreational fishers are concerned about potential restrictions to fishing from marine reserves or “no take” MPAs. Fisheries are a historically important and socioeconomic relevant use of the coastal zone with a well established constituent base. Because of the many types and widespread nature of fisheries, establishing marine reserves almost anywhere in U.S. waters is invariably contentious to at least some fishermen. The socioeconomic and cultural impacts on historic uses of a specific area should be balanced with the sustainability and biodiversity protection that marine reserves have been shown to provide.

While the Federal government retains the power to regulate commerce, navigation, power generation, national defense and international affairs throughout state waters, states have the authority to implement zoning based on their right to manage, develop and lease resources throughout the water column and on and under the seafloor (USCOP, 2004). From a federal perspective, State ocean zoning plans should integrate state coastal zone management programs with offshore activities.

Marine zoning in federal waters may be modeled after use restrictions on federal public lands. As Courtney and Wiggen (2003) note, “federal lands share with the ocean several important characteristics: public ownership, high natural resource and economic value including recreation; policy debate over resource conservation versus economic utilization, multiplicity of agencies and laws; and a significance to local, regional, and national interests.” However, marine ecosystems feature highly mobile resources and there is often great difficulty in controlling access to marine systems, and thus zoning in these areas might require a somewhat different approach to zoning than that currently in place on land.

Marine zoning can be an effective tool to minimize the risk of damage to habitats and resources. Risk assessments require three types of information: 1) the classification of ecosystem components as delineated by their vulnerability to environmental stressors, such as food supply, mechanical disturbance or contamination; 2) the distribution and degree of effort of human activities in the areas of concern; and 3) the impact of these activities on specific ecosystem components. The last requires knowledge of the sensitivity and recoverability of damaged habitats and biota. Informed with these assessments, zoning can be established to conserve or minimize loss of ecosystem diversity, including rare or endangered species and fragile habitat structures. Further, establishing zones restricting specific human activities establishes baseline conditions for evaluating the impacts of the same types of activities in similar but unmanaged areas. Notably, although the suite of human-activity stressors can be broad, risk assessments for these rely largely on a common set of data for habitats, biota and ecosystems processes.

Marine protected areas (MPAs) are a component of a comprehensive marine zoning plan. Applied widely throughout the world, MPAs are a management tool that governments use to protect and restore resources in estuarine, nearshore and offshore areas. The U.S. presently has an estimated 2,000 marine managed areas established by approximately 200 state and federal programs (http://www.mpa.gov). NOAA is now working with federal and state agencies and other stakeholders to develop a national system of MPAs -- including federal, state, and perhaps tribal and local sites -- to protect representative habitats, and natural and cultural resources of national and regional importance. Beyond the EEZ, increased economic activity and global conservation agreements will require a higher level of cooperation, and have already led to calls for the creation of high seas MPAs.

While MPAs are an integral part of a larger ocean zoning scheme, zoning is also used as a tool within MPAs, most notably domestically within national marine sanctuaries and internationally by the Great Barrier Reef Marine Park in Australia. The National Marine Sanctuary Program (NMSP) has the authority to establish zones to help protect sanctuary resources and qualities from the impacts of human uses. National marine sanctuaries have used zoning for over 20 years to protect resources and manage conflicting uses; the NMSP's experiences and techniques will be a valuable component of considering broader ocean use zoning.

In the coastal zone, land use planning, habitat restoration, land conservation, and the development of new technologies to mitigate environmental impacts will continue to be the primary approaches to reduce the impacts of human activities. Current patterns of growth that encourage low density sprawl and consume agricultural and forest land are a major threat to water quality and habitat. A few states are now working to promote "Smart Growth" which advocates compact, transit-oriented development and conservation of resource lands.

Local governments are responsible for most land use decisions in the coastal zone, and these decision makers need information, data, tools and technologies, and a directed education program to assist them in minimizing the impacts of new development, protecting sensitive areas, and planning for the potential impacts of climate change, sea level rise, and coastal hazards. In 2004, the Coastal States Organization sponsored a survey of state coastal resource managers to better understand their science and technology needs. Managers identified land use and habitat change as their top two management concerns at both the national and regional level (CSO, 2004).

The past half century has seen tremendous losses in tidal and nontidal wetlands, seagrass beds, and other vital habitats. The joint EPA /NOAA / FWS / USGS *National Coastal Condition Report II*, states that the "indicators that show the poorest conditions throughout the United States are coastal habitat condition, sediment quality, and benthic condition." While many inputs of nutrients and chemical contaminants have been reduced through source reduction and point source controls, non-point sources of these pollutants continue to be significant threats to coastal and marine habitats.

These habitats must be protected from further degradation and restored to ensure healthy, functioning ecosystems as well as provide for the sustainable production for the nation's fisheries among other ecosystem services. Protecting and restoring coastal habitats requires a watershed approach to comprehensively address threats from physical alterations, pollution, and other impacts. These efforts require not only long-term ecosystem monitoring efforts, but directed research as well. Once thought to be the sole responsibility of government, land conservation and restoration have increasingly been undertaken by private conservation organizations at the national, state and local level.

The development of new technologies based on research and monitoring data to mitigate environmental impacts will become an increasingly important tool for healthy watersheds, coasts and oceans. These ranges from new techniques for stormwater management, to oil spill cleanup technologies, to vessel monitoring systems that help enforce fisheries regulations, to accurate and timely forecasts and coastal modeling efforts. As new technologies become available, they will provide valuable tools to resource managers seeking to protect and restore coastal and marine ecosystems.

NOAA's Role

NOAA's mission, "to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs," clearly outlines a major role for the agency in preparing to meet these challenges (NOAA Strategic Plan, 2005). As the NOAA Strategic Plan notes, "NOAA has a unique mandate from Congress to be a lead federal agency in protecting, managing, and restoring these marine resources."

Specific authorities for NOAA's responsibilities that relate to coastal zone management and marine zoning include:

- Coastal Zone Management Act (1972)
- Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) – Section 6217
- Magnuson-Stevens Fishery Conservation and Management Act (1976)
- Oil Pollution Act (1990)
- Coral Reef Conservation Act (2000)
- Endangered Species Act (1973)
- National Marine Sanctuaries Act (1972) and site specific statutes
- National Offshore Aquaculture Act (2005)
- Executive Order 12906 (Coordinating Geographic Data Acquisition and Access)
- Executive Order 13158 (Marine Protected Areas)
- Executive Orders 13178 and 13196 (Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve)

A key challenge to integrated management of the coastal and marine environment is the fragmented nature of existing authorities, plans and programs. Current ocean plans and zones are typically based on the requirements of a particular sector and/or geographic location, with little recognition of its relationship to other uses, or to the complexity of the underlying ecological system. This was noted by the U.S. Commission on Ocean Policy and the Pew Commission, both of which recommended significant organizational changes to address the problem. In the absence of these major changes, NOAA will need to take a leadership role in working with other federal, state and tribal authorities responsible for coastal and marine decision making. New structures and processes will need to be established to provide a framework for integrated decision making, and additional scientific understanding will be needed to inform these processes. Some efforts already have begun through the U.S. Ocean Action Plan and Executive Order 13158 (Marine Protected Areas).

II. Science Capabilities necessary to support Future Decision Making

To address the complexity of coastal and marine management issues, research, and the synthesis of existing research for use by managers and decision makers, is needed in a wide range of areas (below). A unified concept of habitat types and communities, and therefore ecological classification, is of fundamental importance to a suite of marine issues such as the assessments of coastal zone management areas, MPAs, environmental quality reports, and fisheries management. It will be increasingly important to be cognizant of the structural, compositional as well as functional properties of ecosystems and habitats, as they relate to specific issues in the Coastal Zone and integrate these attributes together to form a more coherent, ecosystem-based approach to coastal management efforts.

Natural Science

- Resource characterization – to improve our understanding of the extent, location, life stages and quality of natural and cultural resources in the coastal and marine environment.

- Seafloor Mapping – to improve our bathymetric data collection and information about the composition of the seafloor.

- Effectiveness of Best Management Practices (BMPs) – to provide data on the effectiveness of recommended practices to mitigate the impacts of human activities in the coastal zone and marine environment (e.g. pollution control, aggregate extraction, coastal engineering).

- Monitoring – to continue to collect baseline biological, physical, and chemical data in order to assess changes over time. Monitoring is an essential component of adaptive management, and is needed to understand resource status and trends, oceanic and anthropogenic factors that influence resource health, response to management actions, and to predict recovery trajectories.

- Species – to continue to collect life history and habitat requirements in order to determine the appropriate types of management tools to employ, including spatial and temporal closures, spawning closures, habitat protection and restoration, take restrictions, etc.

- Habitat – to improve mapping and trends analysis, and to enhance understanding the functional linkages between habitat types (including watershed impacts), and the sensitivity and recoverability of habitats.

- Connectivity – to understand the linkages between species, their life stages, and the priority habitat areas for conservation.

- Restoration science – to establish the scientific foundation for restoring coastal and marine habitats and their functionality (including efforts to restore "dead zones").

- Chemical contaminants – to continue to identify chemical impacts and true effects levels, including sub lethal effects which lead to reduced viability in combination with other environmental stressors (Peterson et al, 2004); effects on egg and larval stages; links to harmful algal blooms; and identification of sources and sinks in coastal and ocean systems.

- Mariculture – to improve understanding of the impacts of coastal and shelf aquaculture on ecosystems.

- Nonindigenous species – to improve the early detection; treatment and prevention techniques associated with invasives.

- Cumulative effects – to understand cumulative and secondary impacts of multiple stressors on coastal and marine ecosystems.

Social Science

- Patterns and types of human uses of coastal and marine environments – to identify how and where coastal and marine areas and their resources are being used, both for extractive and nonconsumptive purposes.

- User conflicts – to understand how different uses conflict, how these conflicts can be minimized and how uses can be prioritized in ways that provide maximum protection.

- Attitudes, perceptions and beliefs – to identify the underlying motivations that may influence human preferences, choices and actions (see also White Paper #6 below).

- Economics – to describe economic conditions and trends associated with the allocation and use of coastal and marine resources, including market and non-market values, costs and benefits, and positive and negative impacts associated with activities, including impacts on coastal communities and industry.

- Cultural heritage and resources – to characterize historical and traditional artifacts in and from coastal and marine areas.

- Governance, Institutions and Processes – to understand the formal and informal institutions responsible for managing coastal and marine resources, and elements of successful processes to integrate coastal decision making.

Source: (National Marine Protected Areas Center, 2003)

Technology and Tools

- Predictive models – to enable researchers and decision makers to understand the potential consequences of sea level rise, other coastal hazards, watershed management BMPs, fisheries management options, harmful algal blooms, designation of Essential Fish Habitat, etc.

- Technology – to provide new tools needed for a wide range of coastal science and management activities, including pollution control, navigation, monitoring equipment, and lower cost remote sensing.

- Decision support tools – to enhance planning and public engagement (e.g., web-based GIS applications), improve emergency response (e.g., spills, collisions), and engage coastal decision makers with the information needed for sound management.

Sources: CSO (1994); Pew Commission (2003), USCOP (2004).

Research and technology development in these areas could significantly improve managers' ability to address the challenges they face in conserving coastal and marine resources. In addition, approaches are needed to meaningfully integrate natural and social science information in a spatial framework. This integration is a critical component of an ecosystem approach to management. As NOAA moves toward this integration, a common approach is the use of map overlays to illustrate different data sets for a geographic area, allowing managers to identify linkages between uses, conditions and resources. However, not all data can or should be presented spatially, and methods must be adopted to integrate this critical contextual information. Another challenge is the effort required to identity, obtain and format data for a common geographic boundary.

Such mapping tools have been used by MPAs in the U.S. and other countries to identify various zoning options for public comment. These experiences highlight the risks and rewards of such a spatially integrated approach. Zoning maps can serve as a flashpoint when introduced too early in the process, if they fail to include key data, or if based on data distrusted by stakeholders. However, they can also be powerful consensus building tools when stakeholders are involved in the data collection and when data analysis and decision rules are transparent.

To facilitate decision making, scientists and managers will need to engage in a continuous dialogue that guides research priorities and delivers scientific results in a form managers can use. This type of dialogue will likely need to be mediated through targeted education and outreach programs that will provide the link between the separate research science and coastal management audiences.

Section III. Partnerships Necessary to Effectively Address the Emerging Issues

The complex suite of resource dependent commerce, land and water based resource users, and conservation interests and goals requires an equally complex, participatory mix of public and private sector partners to support science to management action. Participants should include federal, state and tribal agencies, universities and institutes, industry, and non-governmental organizations (NGOs). Lessons also can be learned from other countries and international organizations. Key partners include:

- Researchers, data/information collectors, and analysts are needed to research, collect, store, and analyze the data; test the technology; and develop the information necessary to support sustainable management.

- Trainers and educators are needed to develop the applications, tools, coursework, and information documents necessary to train, educate, and transfer information to on-site staff and managers who then may apply what is learned.

- Resource managers are the front line people on the ground and in the water making the daily decisions that affect the health of the nation's resources. They apply the information and techniques to management problems; develop and adapt resource management plans in cooperation with the public; evaluate the effectiveness of management actions; and identify research necessary to conserve and restore resources. In addition to traditional resource managers (e.g., State and territorial, federal, tribal, regional, local and international) and the already robust management of coastal lands by the private sector (e.g. private forests and conservation easements), the nearshore marine environment is likely to see increased management by NGOs in partnership with government (e.g. The Nature Conservancy and many additional local and regional land trusts).

- Opinion makers, opinion influencers, and information sources, i.e., the media, will play a significant role in enhancing public and decision-maker understanding of coastal and marine ecosystem issues, problems and solutions; encouraging participation in decision making; and influencing behaviors that affect coastal and marine resources. The ability to synthesize and transfer information to the public is critical to management success in this increasing complex management environment. Resource management initiatives cannot be optimized, and indeed are likely doomed to failure without public "buy-in" and active support.

- Resource users and other stakeholders are critical partners in developing coastal management and/or marine zoning initiatives. Resource users often have significant impacts on marine natural and cultural resources, and resource management decisions may have substantial economic and social impacts on users. Activities of concern can be extractive (e.g., fisheries, oil and gas, sand and gravel, seabed mining, bio-pharmaceuticals, desalinization, etc.), non-extractive (e.g. tourism, recreation), constructive (e.g., development), agricultural, silvacultural, aquacultural, or conservation-focused. To be successful, coastal management and marine zoning efforts must provide an opportunity for stakeholders to participate throughout the process. Stakeholders can also bring a wealth of knowledge about marine resources, uses and impacts to inform decision making.

- Government decision makers (e.g., elected and senior government officials at all levels) must be involved since they ultimately make the policy decisions, determine program direction, approve program cooperation and coordination, both domestic and foreign, and provide the funding and staff resources necessary for ecosystem-based management. The existing high competition for limited available fiscal resources will likely continue. At the same time, competition for use of coastal and marine resources, including at the trans-boundary and deep ocean level will increase.

NOAA's programs can address the vast majority of ecosystem management questions and issues, and partner with the broad spectrum of agencies, organizations, industry, and the public identified above. Successful implementation will require not only unified action by the program components of the Ecosystem Goal Team, but also linkage with the Commerce and Transportation, Weather and Water, and Climate Goal Teams (e.g. conflicts between marine transportation and other resource use; land use planning to mitigate coastal hazards and climate change).

Section IV – Benefits to NOAA, constituents, society in general from this effort

While the challenges of comprehensively addressing an integrated approach toward coastal management and ocean zoning are considerable, the consequences of failing to act are even more dramatic. The Ocean Conservancy, in partnership with many other NGOs, already has documented the phenomenon of "shifting baselines" – failing to see the cumulative changes in our environment because these changes occur over several generations (http://www.shiftingbaselines.org). Coastal ecosystems around the nation area are bearing the impacts of excess nutrients, habitat loss, depletion of keystone species and impacts of invasive species, all of which have led to a significant degradation. This degradation is already leading to economic as well as environmental losses and must be reversed. NOAA clearly has the capability to conduct research, deliver information, and help society identify and set appropriate targets for long-term conservation and sustainability.

In addition, rationalizing the use of space within the coastal zone and the marine environment will provide a stable environment for economic growth in relatively new sectors, such as aquaculture and bio-prospecting. With sound zoning to minimize conflicts, and environmental safeguards, these activities could become part of a thriving, sustainably managed coastal and marine economy.

NOAA is well positioned to play a leadership role in helping local, state and federal decision-makers work with stakeholders to develop a comprehensive approach to coastal and ocean management. NOAA's "wet side" can provide this leadership, expertise and tools by:

- Improving and expanding our ability to conduct coastal and ocean ecological forecasting and warnings in coastal and offshore regions such as those associated with recent harmful algal blooms and also with the implementation of telemetry efforts associated with the Integrated Ocean Observing System (IOOS) to improve near real-time coastal data delivery to managers.

- Providing the scientific support to build a truly integrated CZM capability for the U.S. that focuses on the land-water interface, as well as the EEZ and beyond.

- Providing the scientific knowledge and management support technology (including data management and visualization) necessary to objectively address the growing land based stressors and increasing use of the ocean and its resources.

- Developing strategies based on the best available natural science, social science and economic data to manage fisheries and other competing uses of the Nation's marine resources in concert with the development of a national system of MPAs.

- Bringing NOAA science, technology and tools to partnership efforts with federal agencies, states and tribes responsible for managing the nation's diverse coastal and marine resources .

NOAA's mission includes a responsibility to "conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs." The laws that drive NOAA's programs and requirements also make clear that we must undertake this mission not just for ourselves, but for the sake of future generations. NOAA's science programs and partnerships are the foundation of this effort, and must be more firmly linked to the management outcomes so critically needed in our coastal and ocean environment.

To this end, there are a number of specific management actions NOAA can take:

- Complete and release the zoning policy paper for the National Marine Sanctuaries Program, which outlines how the NMSP considers and creates zones within sanctuaries. This policy paper can serve as an example for other organizations on how to develop and implement zones within marine protected areas.

- Support the development of a national system of MPAs as a key element of a future marine zoning plan. The national system of MPAs is now being developed by NOAA and the Department of Interior in cooperation with other federal, state, and tribal agencies as well as stakeholder groups. It will enhance the management of and linkages between existing MPA sites and programs, as well as facilitate regional planning processes to identify conservation priorities in need of additional protection.

- Work through the Subcommittee on Integrated Management of Ocean Resources (SIMOR), formed as part of the U.S. Ocean Action Plan to guide federal agency coordination of ocean management. Through SIMOR, NOAA can help develop coordinated approaches to ocean zoning. Federal agencies can take a leadership role in moving toward zoning in federal waters to accommodate the increasing number and types of uses.

- In state waters, NOAA and other federal agencies should continue to work in partnership with coastal states and tribes as they begin to develop regional governance structures and management strategies. In support of these efforts, NOAA should bring together technical, scientific and management staff responsible for key resources and uses within the region. By forming cross-disciplinary, cross-NOAA working groups to support specific regional goals, NOAA can enhance its capacity to integrate data within a spatial framework that will be fundamental to future zoning efforts.

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Ecosystem White Paper #5

Near- Real Time Ecological Forecasting

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Abstract

A key mission for NOAA is to develop scientifically sound ecological forecasts relevant to NOAA's mission, practical to its customers, and providing a necessary underpinning of ecosystem-based management. NOAA must strive to integrate its research and provide the best forecasts as efficiently and effectively as possible. Ecological forecasting is a very young and interdisciplinary field that will capitalize on NOAA's existing physical and biological expertise. This document provides an initial look at NOAA's current capability for ecological forecasts from near-real time to periodic forecasts. Issues related to human health, water quality, and disaster planning often demand near-real time forecasts while for other applications such as determining the impacts of management decisions or assessing the health of a species or ecosystem, a seasonal, annual, or scenario forecasting capability will suffice. We also discuss some of the needs, issues, and challenges the Agency will face in the next 15 years as this field of science matures.

I. Description of Issue:

The health of the U.S. economy is inextricably linked to the health of our Nation's ecosystems and the goods and services they deliver to our economy. Each year U.S. ecosystems provide over $227 billion in added value to the U.S. economy (USDA, 1999; CENR, 2001) as well as other harder to quantify services and benefits such as waste detoxification and decomposition; air and water purification; maintenance of biological diversity; and recreational and spiritual renewal (Daily et al., 1997). Coastal ecosystems, in particular, provide a wealth of fisheries resources, recreational benefits and are a potential source of life saving pharmaceuticals. These important ecosystems can also directly impact human health from exposure to contaminated water (e.g., from urban and agricultural runoff, pollutants, coliform and other pathogens, toxic algae) or contaminated food (e.g., fish and shellfish).

Sustaining productive ecosystems, and restoring damaged ones, depends on our ability to understand and predict the impacts of human activities and natural processes on those systems and to forecast ecological change. Policy makers, natural resource managers, regulators, and the public often call on scientists to estimate the potential ecological changes caused by these natural and human-induced stresses and to determine how those changes will impact people and the environment. During the last decade, using technological and scientific innovations, scientists have developed and tested forecasts in ways that were not feasible only a few years ago (Clark et al., 2001), signaling the emergence of a new and challenging science called "ecological forecasting".

***What is Ecological Forecasting?* –** Ecological forecasts predict the impacts of physical, chemical, biological, and human-induced change on ecosystems and their components (CENR 2001). Extreme natural events, climate change, land and resource use, pollution, and invasive species are five key drivers of ecosystem change (CENR 2001) that interact across wide time and space scales (hours to decades and local to global) (Figure 1). Ecological forecasts aim to understand, predict, and provide information to mitigate the impacts of these stressors on ecosystems. In much the same way a weather or economic forecast can help society plan for future contingencies, an ecological forecasting capability is necessary for environmental managers to make informed decisions regarding alternative management scenarios and to take appropriate actions to affect those conditions and better manage our Nation's coastal resources. Ecological forecasts give managers the tools to answer 'what-if' questions about the ocean and coastal environments and provide a bridge between research science and governmental policy. Ecological forecasts also have the potential to provide widespread societal and economic value to the country. These values include improved decision-making for coastal stewardship, mitigation of natural events and human activities (e.g., land-use practices, fishing), reduced risks to human health, reduced impacts of natural hazards, enhanced communication between scientists, managers, and the public and, overall, more effective prioritization of science.

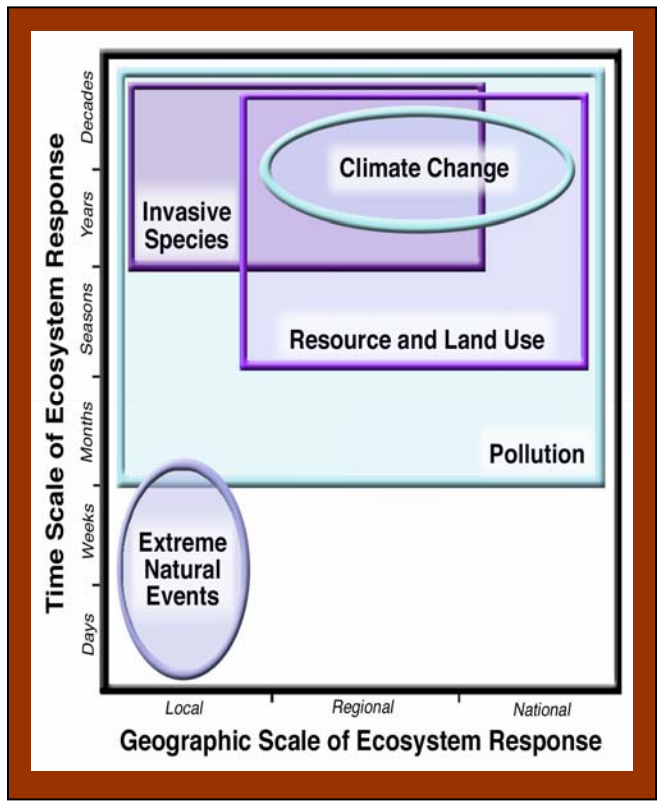

Figure 1. Time/Space Scale of Ecosystem Response. The five key ecosystem stressors – pollution, land and resource use, invasive species, extreme natural events, and climate change – can challenge the integrity of ecosystems and impede the delivery of their goods and services. These stressors can act alone or together, and their cumulative effects are poorly understood. Ecosystem responses are as varied as the inputs that strain them, playing out in scales from hours to decades and from local to global. Figure is reproduced from NOAA Technical Memorandum NOS NCCOS 1, p2.

***Types of Ecological Forecasts* –** There are many types of potential ecological forecasts. Some will be like weather forecasts with predictions of what is likely to happen in a particular location in the short term (e.g., sea nettle swarms in the Chesapeake Bay, the landfall of harmful algal blooms, beach closings, drinking water quality or the movement of oil spills, coral reef bleaching events). Others, however, will focus on much longer term and larger scale phenomena (such as year-to-year variation in fish stocks, extinction risk of endangered species, new invasive species encroachment, rates of habitat restoration, effects of climate change on biota and water quality and quantity).

Specific issues within each of these categories of stressors are listed below:

Extreme Natural Events – Such events may include extreme changes in water resources, severe spring storms and hurricanes, extreme climate variation (e.g., an exceptionally cold or warm year compared to the average), shifts in marine populations, hypoxic/anoxic events and toxic algal blooms. The ability to predict the occurrence of these events and their ecosystem effects, as well as their interactions with other causes of change is important for planning management and response activities.

Climate Change – Such events may include changes in sea level, large scale ecosystem drivers (e.g., current patterns, storm tracks and frequency), nutrient flow regimes and the extent of "dead zones", the amount of precipitation and river flow. Climate change may be reflected as a change in the mean or trend of a parameter, shifts in seasonal cycles, or extreme events (e.g., coral bleaching, ENSO). To plan and minimize impacts of these events resource managers currently need forecasts of the interaction of climate change and variability (e.g., sea surface temperature changes, freshwater input, coastal nutrients) with other stresses on ecological integrity, goods and services (e.g., fisheries, water quality and quantity), particularly the distribution and abundance of species, production of ecologically/economically important species, and the availability to clean water.

Land and Resource Use – Fishing can dramatically change the structure and function of an ecosystem by removing predators or prey in the food web. Such changes may cause changes in the abundance of less desirable species, some of which can cause a degradation of the overall quality of the system. The ability to predict the ecosystem consequences of various levels of fishing effort is critical for the management of ecosystem resources. Additionally, changes in coastal ecosystems may be linked to changes in land and resource use, which is often associated with agriculture or local urbanization and resultant nutrient loadings and deterioration of coastal habitat. Current needs include forecasts of changes in the health and productivity of the ecosystems that are critical in providing food and recreation.

Pollution - Concerns about the presence of potentially harmful chemicals and excess nutrients in the environment remain a top concern. Current needs include forecasts of the effects of air pollution and land-based activities (e.g., agricultural production, forest harvest, urban growth and residential development, waste disposal, toxins, etc) on aquatic ecosystems. The damage to the ecosystem may be direct (e.g., hypoxia/anoxia, harmful algal blooms), or may impact goods and services (e.g., fish consumption advisories).

Invasive Species - Invasive species are species that are introduced intentionally or accidentally from other geographic areas, and are capable of spreading rapidly and replacing native species. These invaders exist in nearly all U.S. ecosystems, pose potential threats to the integrity of biodiversity and ecosystems, and annually cost billions of dollars. Current needs include forecasts of the conditions favorable to the introduction, spread, and ecological impacts of potential and already-introduced species.

Interactive and Cumulative Effects – Large aquatic ecosystems are subject to multiple causes of ecological change. For example, an extreme natural event may open the door for new species invasions, and the success of that invader may be enhanced by altered climate (new precipitation and temperature patterns), the extent to which the land and related resources are used, and the chemical condition of the environment being invaded (pollution, nutrients). The cumulative impact of threats may be greater than the sum of individual impacts. Building the ability to forecast the cumulative effects of these multiple stresses is one of the most significant challenges for applied ecology.

As seen from the list above, ecological forecasts can span a wide range of issues and space/time scales and involve a multitude of biological factors (e.g., life history traits, behavior, species, population and ecosystem interactions) as well as physical and chemical factors, and a diverse user community. Ecological forecasts can also involve predictions that are independent of time and involve “scenario testing” or examination of alternative management scenarios (e.g., impacts of nutrient reductions, the setting of harvest levels, and ecological effects of sea level rise). Models are often used to conduct forecasts, but these are just one of many tools (e.g., satellites, sensors, test kits, etc.) that can be used and integrated to provide valuable ecological forecasts for management applications.

***NOAA’s Role in Ecological Forecasting* –** Ecosystem forecasts have been gaining momentum for the past few years, particularly among academics (Clarke et al., 2001) and federal agencies (NOAA Report 2001). The President’s Committee on Environmental and Natural Resources (CENR) produced a 2001 report on Ecological Forecasting and stressed the Nation’s need for developing forecasts of ecological change. Since 2001, NOAA has formalized the development of an Ecological Forecasting capability for resource managers that entails a partnership across all NOAA line offices and with universities and other federal agencies around all the coasts and Great Lakes. The report of the U.S. Commission on Ocean Policy also highlights the importance of ecosystem-based management and its reliance on the development of predictive capabilities for ocean ecosystems, providing further justification for NOAA to undertake ecological forecasting to support its ecosystem-based management responsibilities.

NOAA Strategic Planning has recognized the importance of ecological forecasting by including it in recommendations of the recently published NOAA 5-year and 20-year research plans. The following language is used, “Ecosystem prediction is perhaps the most complex challenge NOAA faces. With a better understanding of the inter-relationships among biological, physical, chemical, hydrological, and socioeconomic variables, NOAA will develop adaptive, ecosystem-based management tools to deal with coastal challenges related to fisheries, urbanization, changes in habitats, watersheds, and the relevant airsheds. This will include better quantification of ecosystem effects, or limits on ecosystem productivity, and associated uncertainties". Specifically mentioned in the 20 year NOAA research vision in the area of understanding global ecosystems to support informed decision-making is the following:

- Forecast and mitigation strategies related to anoxia/hypoxia, harmful algal blooms (HAB) and toxins in the food chain, beach closure, invasive species, waves, air/water quality and quantity;
- Ecological assessments and predictions of impacts from climate changes (e.g., coral bleaching, shifts in distribution of fish stocks, shifts in marine ecosystem structure and productivity, monitoring climate sensitive "sentinel species");
- Decision support tools and information services for adaptive ecosystem-based management of coastal resources (e.g., regular assessments of ecosystem state, 'event' bulletins, satellite synthesis products, defining marine protected areas [MPAs]).

A dedicated ecological forecasting capability is critical for the Agency to achieve the mission and goals set out in the NOAA Strategic Plan to "understand and predict changes in the Earth's environment and conserve and manage coastal and marine resource" (Mission Statement); "protect, restore, and manage the use of coastal and ocean resources through ecosystem–based management" (Goal 1); and "increase its investments in short- and long-term research in development of advanced technology to understand, describe, and predict changes in the natural environment" (cross-cutting priority). In the NOAA FY07 Annual Guidance Memorandum (AGM) language supportive of ecological forecasting is specified in the sections on integrating global observations; advancing NOAA's modeling capability; providing leadership for the oceans; increase climate information, services, and products; and providing critical information for water resources.

II. Science Capabilities Necessary to Support Future Decision Making

NOAA is well poised and has the legislative mandates to take a leadership role in developing ecological forecasts for coastal and marine environments that will yield significant economic and societal benefits to the nation (Appendix 1). Ecosystem-based management, a critical mission for NOAA, will not be possible without ecological forecasts. Through its comprehensive research investments, NOAA is developing the knowledge about ecosystem structure and function (i.e., physical, chemical, biological, and human interactions) necessary to develop ecological forecasts. These knowledge-based products include everything from applied research efforts to long-term observations. NOAA is also developing the infrastructure necessary to support ecological forecasts through the development of regional observing systems, coupled physical-biological models, sensors, and computational and data visualization/presentation capabilities. Together, these research and infrastructure capabilities have led to a suite of successful ecological forecasts with many more currently in development (Appendix 2).

The complexity of the ecosystem approach demands a suite of complex, often linked, models, tools and technology to provide a scientific basis for decision-making (e.g., linkage of airshed, watershed, and water quality and fisheries models). To achieve this full capability for ecosystem-based management, over the next decade, NOAA will need to develop integrated ecological forecasting systems. As one approach, NOAA has proposed to establish or enhance existing regional centers for ecological forecasting that will be responsible for developing and transferring to the management community a suite of regionally-specific, integrated ecosystem modeling and ecological forecast tools that will provide a scientific basis for the proactive and complex decisions that must be made at all levels of government. Having the regional centers and other NOAA ecological forecasting research programs associated or collaborating with the Integrated Ocean Observing System (IOOS) regional ocean observing systems will allow for regionally-coordinated planning for observations and models, and bring in regional user groups. Real-time integrated observing systems can also provide critically needed information to assess natural scales of variability, provide drivers for forecasting models and provide data to test the accuracy and precision of forecasts.

The establishment of regional ecological forecasting centers will allow NOAA in conjunction with other Federal, State and local partners to 1) bring together research, monitoring, and modeling efforts to understand ecosystem composition, structure, and function, and to monitor ecosystem status and trends; 2) identify the requirements of the regional management community through workshops, focused studies, and continuous engagement; 3) track, coordinate, and integrate where possible ecosystem and socioeconomic modeling efforts within and external to NOAA; 4) identify critical gaps in knowledge for each region; 5) use competitive internal and external funding to ensure those gaps are filled; 6) transition models, tools, and forecasts to operational status; and 7) provide predictions for management decisions at all ecosystem scales.

To reinforce and build NOAA's capability in ecosystem forecasting, a number of research, procedural and tool development needs have been identified along with a diverse set of challenges:

<u>Research Needs:</u>

Research into anthropogenic stresses to ocean, coastal, and Great Lakes ecosystems have centered primarily on the effects from over-fishing, habitat degradation and declining water quality as well as natural physical hazards. Less is known about the linkages among climate change, food webs, physical-biological coupling and ecosystem production dynamics. Understanding the fundamental knowledge base of ecosystem structure and function will allow NOAA to develop a suite of robust ecosystem forecasts addressing such conditions as HABs, anoxia, fish distribution and abundance, beach closings, coral bleaching, and water quality and quantity. This research, by its very nature, is long-term. Specific types of research needs include:

- Define the time and space scales needed to capture the fundamental physical and biological drivers that are required for ecosystem forecasts.

- Measure the natural scales of variability regarding physical-biological coupling, food web dynamics and ecosystem production.
- Define the observational needs to drive ecological forecasting models, assess the accuracy of model forecasts and assess the impact of management decisions on resources and habitat quality.
- Develop and test new sensors for physical and biological observing systems.
- Increase the understanding of ecosystem composition, structure, functioning, and variability and the connection between the abiotic and biotic components of coastal ecosystems. This includes an understanding of large-scale ecosystem drivers and an understanding of ecological communities, including interactions among species (including little-studied "hidden players" such as viruses, microbes and invertebrates), the physical environment, evolutionary history, and the "assembly rules", if any, by which ecosystems are formed.
- Increase the understanding of ecosystem indicators and establish thresholds and breakpoints within ecosystems, beyond which there are concerns or needs.
- Conduct comprehensive process studies to understand the ecological mechanisms producing ecosystem patterns and to define ranges for key physical and biological parameters within ecosystem models.
- Conduct integrated ecosystem studies involving observations, research, model development, and process studies. This will allow for increased understanding of connections among ecosystem drivers and functions as well as the ability to quantify key biological parameters and species dynamics necessary for biological models.

Procedural and Tool Needs:

- The need for true interdisciplinary scientific integration between scientists and agencies of the physical, geochemical and biological aspects of ecosystem process and function.
- The need for strong connections with developing regional associations or IOOS, involving integrating multiple technologies (e.g., satellites, observation platforms, ship surveys, biological sensors).
- The need for fully integrated, spatially explicit, coupled hydrodynamic and biological models with appropriate links to watershed and higher tropic level models on key ecological scales to support place-based ecosystem management.
- The need for robust physical modeling platforms to provide the foundation with which to embed biological models. Most ecological forecasts NOAA will perform involve the movement of water so an accurate physical hydrodynamic model (i.e., 4-dimensional) is a necessity (e.g., larval transport, HAB forecasts, etc). Within this framework, various biological components could be added depending on the issue and forecast.
- The need for robust biological models capable of predicting distributions, behaviors, and interactions among biota (e.g., movement, predator/prey dynamics, growth, death, reproduction processes).
- The need to address data issues such as the integration of disparate data sources, establishing and enforcing data integrity, formatting output for appropriate

decision support software, satellite data calibration and validation, archiving forecasts, as well as the data upon which they are based.

Challenges:

- Ecosystem science is highly complex.
- A single generic one-size fits-all forecast is not possible. Rather a series of predictions tailored to the local or regional needs will be necessary due to a diversity of issues and users.
- Physical and biological components of ecosystems are grossly undersampled with current technologies and effort levels.
- Deciding the types of forecasts for specific regions, location where these forecasts will be operated, and who will run, maintain, issue and fund the forecasts.
- Deciding when forecasts are ready for dissemination and when to inform the public.
- Developing and disseminating science-based assessments and information to decision makers in understandable and utilizable formats.

NOAA, as the primary federal agency for ocean science supporting a variety of societal needs, is both an initiator and user of ecological forecasts. As an enabler, NOAA provides resources and personnel to collect the data, develop the forecasting products, summarize scientific results for decision makers, produce assessments, and disseminate the synthesized results and information. The agency expects to use many of the forecasts to support its stewardship role. NOAA's ecological forecasting capability will be improved by the ability to simulate ecosystem complexity with coupled physical/biological models and data assimilation; and developing new models to predict ecological outcomes from alternative scenarios and for facilitating the evaluation of management plans. These integrated forecasting systems will also foster the transition/operationalization of forecasts by assessing forecast accuracy, sensitivity, and error; defining acceptable levels of accuracy for proposed forecasts; enhancing risk assessment tools for management scenarios; linking socioeconomic cost-benefit analysis to ecological forecasts; developing testing and comparison metrics for forecasts; and developing methods to share, visualize, and communicate forecasts and uncertainty to user groups.

III. Partnerships Necessary to Effectively Address the Emerging Issues

The success of ecological forecasting depends on partnerships at all levels, from universities and local/state governments to other federal agencies. The scale and complexity of ecological forecasts will require that NOAA improve partnerships between the Agency and outside users and constituents and increase interactions among the NOAA matrix programs and goals. NOAA must take advantage of its existing partnerships with other Federal agencies (e.g., IOOS, US Climate Change Science Program), internationally (e.g., GEOSS, IGBP, with coastal states, and users of coastal resources and ecosystems (e.g., commercial and recreational fishers, recreational users). Strong partnerships will help decision makers inside and outside the government to identify the most critically needed forecasts and support efforts to build, test and issue them. Some key elements of those partnerships are emerging but must be made stronger.

University partnerships (extramural research community): NOAA partnerships with the extramural research community are necessary to provide the research understanding and prototype ecological forecasts which will become the foundation for the development of "operational forecasts" within or outside of NOAA. There are several successful examples with NOAA's Joint Institutes and other major extramural research programs (e.g., GLOBEC, ECOHAB, MERHAB, Oceans and Human Health) where integration has occurred. NOAA also has an ongoing program dedicated to the development of ecological forecasts (ECOFORE) which encourages collaboration between university and NOAA scientists as well as the management community.

Local/State government partnerships and user community: The scale and complexity of ecological forecasts will also require that NOAA continue and improve partnerships with outside users and constituents. NOAA partnerships with local and state governments and decision-makers (e.g., beach, fisheries, shellfish, and water resources managers) are necessary for a wide variety of purposes. State and local governments are one of the principal coastal management decision makers and therefore the true users of the ecological forecasts. The information they provide regarding management needs will help define the types of forecasts produced, the level of accuracy required, and the most appropriate vehicles to disseminate the information. Other users include boaters, coastal landowners, recreational fishers, divers, surfers, the beach-using public and commercial enterprises. Once forecasts are developed these users can provide an ongoing feedback mechanism to identify needed improvements in forecast capabilities and to provide direction for future research. Local and State governments may also be involved in the actual transition, operation, and maintenance of developed forecasts. Establishing connections with the user community is critical during the development and transition of forecasts and NOAA engages this community through a variety of mechanisms that include workshops, surveys, networks, extension and participation in research (e.g., Anonymous 2002; Sturdevant 2004; Hendee et al., 2006).

Federal partnerships (NASA, EPA, USGS, COE, NSF, and USFWS): NOAA fosters partnerships with other Federal agencies to leverage and collaborate on activities related to developing an ecological forecasting capability to support ecosystem management - which is often at a scale larger than the purview of individual agencies. Some of these regional issues include climate change, watershed-

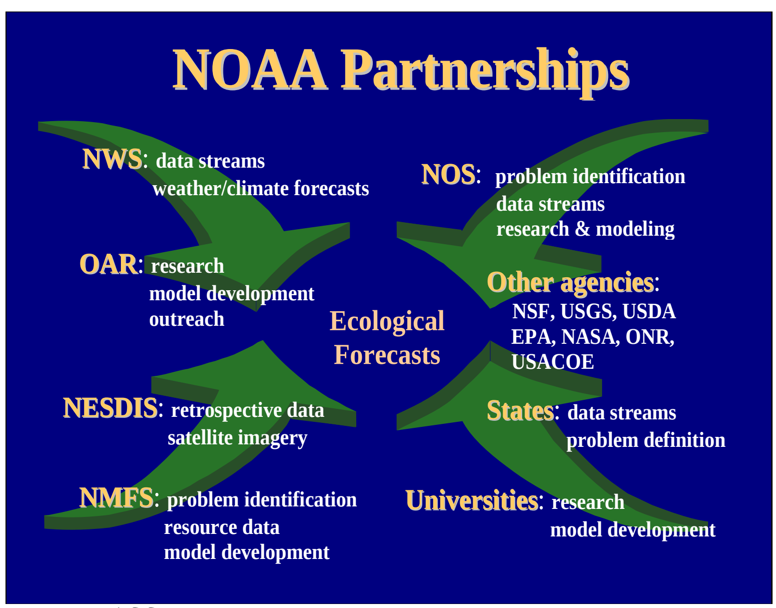

Figure 2. NOAA Partnerships: Schematic illustrates the multitude of collaborations necessary both within and outside of NOAA necessary for the end to end development of many ecological forecasts.

estuary-ocean interactions, coral reef health, habitat restoration, hypoxia, harmful algal blooms and can only be addressed through large-scale ecosystem based programs, the integration of multiple technologies and large scale coordination efforts such as IOOS and regional taskforce, alliance and other collaborative endeavors (e.g., the Great Lakes Regional Collaboration, Gulf of Mexico Alliance, Mississippi River Watershed Nutrient Taskforce) . NOAA is currently working with other agencies on the development of climate change forecasting centers and integrated earth systems frameworks for ecosystem management. The recently released Ocean Action Plan has also established a new ocean governance structure (National Science and Technology Council Joint Subcommittee on Ocean Science and Technology) aimed at integrating the activities of executive branch agencies regarding ocean-related matters and provides another avenue of coordination toward the development of ecological forecasts.

<u>NOAA partnerships (Figure 2)</u>: NOAA is applying its extensive intramural and extramural research capacities and modeling expertise to assure successful development, validation, and demonstration of a wide variety of ecological forecasts. Ecological forecasts result from the integration of data, information, and models produced by multiple scientific disciplines, and thus reflect a multi-disciplinary "Corporate NOAA." For example, a typical forecast may require collaboration between many programs in NOAA including NESDIS (satellite information), the Weather Service (hydrology, wind fields, rainfall), and OAR, NOS, and NMFS (interdisciplinary research, hydrodynamics, food webs). In turn, one part of a forecast may be best operationalized within the NWS whereas another part may be best operationalized within NOS CO-Ops (e.g., Great Lakes forecasting system). This cross-line office and cross-goal aspect of research applications is central to the success of NOAA's ability to conduct ecological forecasts.

Within the agency there are, however, several organizational and procedural challenges.

Organization challenges include:

- How will the development of ecological forecasts be managed through the current Program Planning Budgeting and Execution System (PPBES) structure which contains at least 5 programs working on components of ecological forecasting?
- How will NOAA develop an 'end-to-end' approach for ecological forecasts that includes: user identification, prioritization of needs, funding of research and development, testing of forecast products, planning and funding for the transfer to application, and, when necessary, routine operation of the forecasts?
- If NOAA is the ultimate operational entity, how will NOAA develop the capacity to deal with the accelerating increase in forecast products? If the operational entity is outside of NOAA, how will NOAA develop a robust procedure to assure the most appropriate hand-off for all parties involved?

Process Challenges include:

- How will priorities for research be set given the need for high risk, but potentially high payoff research?
- How does NOAA effectively establish connections with the user community during the development and transition of forecasts?

- How will NOAA define roles and responsibilities for ecological forecasting from a corporate level? Who will develop the forecasts? Who will receive and routinely run the forecasts? What will the users do with the forecasts? How will resources be allocated? If there are no increased budgets, what will NOAA not do? What is the role of Government and what is the role of the private sector?

One of most challenging near-term issues for the Agency is how to prioritize the development and transition to operations of the wide range and diversity of ecological forecasts currently in development. As evidenced in Appendix two, the ecological forecasting capability of NOAA is rapidly advancing on all fronts and the transition to operations of all these forecasts will probably not be possible or warranted given funding constraints and other Agency priorities. Prioritization among potential ecological forecasts will allow NOAA to invest resources and personnel in the most promising products. Potential prioritization criteria and questions are described below:

- Is the forecast a mandate for NOAA's coastal responsibilities?
- Is the forecast within NOAA's mission and goals?
- Should NOAA be the lead?
- What benefits will the forecast have after investment?
- Does investment in the forecast offer collaboration/leverage with other offices/agencies?
- Does investment in the forecast benefit multiple user groups?
- What is the time frame for development of the forecast?
- What is the overall level of investment needed?

NOAA has begun a path toward addressing some of these issues with the recent development of a research to application transition policy. The policy describes the process by which any research result, information, or tool should be transitioned into application. The policy calls for the creation of a Transition Board and of Transition Teams. Figure 3 outlines the process and through this formalized structure, which links together program offices with various NOAA planning processes, can help to prioritize the development and transition of new and ongoing ecological forecasts.

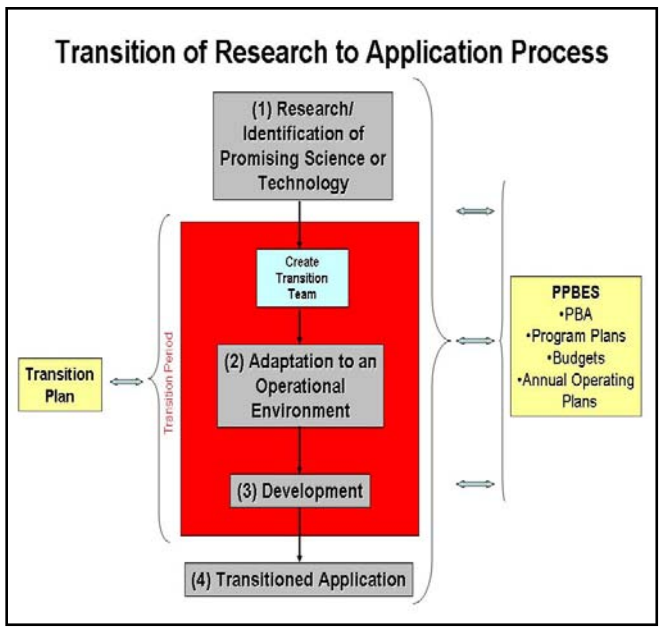

Figure 3. Proposed NOAA Transition Process outlining the steps involved with transitioning any research result, information, or tool into application.

IV. Benefits to NOAA, Constituents, Society etc.

Maintaining ecosystem function and health will benefit U.S. society which demands coastal resources, such as uncontaminated fish and shellfish, access to clean coastal waters and reduced risks to human health. NOAA as a mission agency is charged by Congress and the Administration with specific mandates prescribed by law. Ecological forecasting will aid the agency in its stewardship responsibilities by providing information on future ecosystem-related problems, including feedbacks that affect human health, for which, NOAA can respond and plan for. Ecological forecasts align with at least 24 major ecosystem-related mandates, policies, treaties or international agreements (Appendix 1).

NOAA is developing ecological forecasts for coastal managers in an effort to help merge wide-ranging research and observation programs around this new and challenging science, which ultimately enriches the science-policy interface. Focusing on developing, testing and applying ecological forecasts provides coastal research and management communities with three benefits. First, ecological forecasts will help decision makers better manage the Nation's coastal resources because they provide valuable information for better assessments that predict future conditions of proposed actions and the potential impacts of their decisions. Second, focusing on defining ecological forecasts needs will strengthen the link between research and management by tying management needs to a scientifically challenging agenda. Finally, the desire to build and improve ecological forecasts will help focus NOAA's coastal science agenda by assuring that NOAA's monitoring, research and model development efforts are geared towards the needs of coastal managers who benefit from ecological forecasts.

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Appendix 1 – Drivers related to Ecological Forecasting (Legislative, Policy)

Aquatic Nuisance Species Program USC 4722
Coastal Ocean Program legislation
Coral Reef Conservation Act
Coastal Zone Management Act of 1972 – Amended 1990
Endangered Species Act
Executive Order 12866 for EPA (1993)
Executive Order 13089 (to establish the U.S. Coral Reef Task Force)
Executive Order 13158 (to establish MPAs)
Executive Order 13340 (Great Lakes Regional Collaboration)
Great Lakes Water Quality Agreement of 1978- Amended 1987
Harmful Algal Bloom and Hypoxia Research and Control Act –1998, Amended 2004
Magnuson Stevens Fishery Conservation and Management Act (1976, 1996)
Marine Mammal Protection Act
National Coastal Monitoring Act (Title V of the Marine Protection, Res, and Sanctuaries Act)
National Climate Program Act
National Contaminated Sediment Assessment and Management Act
National Environmental Policy Act
National Marine Sanctuaries Act
Navigational and Navigable waters- water pollution prevention and control (of Great Lakes)
Ocean Dumping Act (Titles I and II of the Marine Protection, Research and Sanctuaries Act)
Oceans and Human Health Act (Title 1X. Section 903 of S. 1218)
Public Health and Welfare – Pollution Prevention and Control (USC 7412)

Sea grant legislation
U.S. Commission on Ocean Policy
U.S. Ocean Action Plan
Water Resource Development Act

Appendix 2 – Examples of NOAA Ecological Forecasts (Operational and in Development)

Ecological Forecast Categories/ Type	Driver - Need	Frequency of Forecast	Spatial Extent of Forecast	Products - Outputs	User Community	Status
Predicting movement of hazardous spills	-Disaster Planning -Living Resource Impact -Human Health Impact	-Near-real time	-Event Specific -Local -Regional	-Trajectory of movement -Risk to living resources and humans	-State managers -Federal managers -Emergency response personnel	-In Development -In Transition -In Operation
Forecasting the distributions, abundance, and health of living resources	-Stock Assessments -Living Resource Impact	-Seasonal -Scenario	-Regional -Species Distribution Range	-Species distribution maps -Species abundance -Probability of rebuilding overfished species -Projects distribution and abundance	-Fishery managers -Fishery management councils -State managers -Resource managers	-In Development -In Transition -In Operation
Forecasting the effectiveness and optimal placement of MPA's	-Stock Assessments -Living Resource Impact	-Scenario	-Regional -Local	-Species abundance, distribution, size structure and habitat maps -Optimal location of MPA's	-MPA managers -Resource managers	-In Development
Predicting coral reef health and recovery after disturbance	-Living Resource Impact	-Scenario	-Regional	-Species survival probability -Habitat maps	-Marine Sanctuary managers -Resource manager	-In Development
Predicting larval transport and survival	-Stock Assessments -Living Resource Impact	-Daily to weekly	-Regional	-Trajectory of movement -Probability of survival at a given location	-Marine Sanctuary managers -MPA managers -Fishery managers	-In Development -In Transition -In Operation
Predicting organism distributions based on habitat mapping	-Stock Assessments -Essential Fish Habitat -Living Resource Impact -Human health	-Scenario	-Local -Regional	-Species distribution maps -Habitat maps	-Local and State managers -Resource managers	-In Development -In Transition -In Operation

	impacts					
Development, persistence, movement and landfall of harmful algal blooms	-Living Resource Impact -Human health impacts	-Near real time -Daily -Scenario	-Local -Regional	-Trajectory of movement -Bloom identification -Probability of bloom initiation	-Local and State managers -Resource managers	-In Development -In Transition -In Operation
Coral bleaching forecasts	-Living Resource Impact	-Seasonal -Scenario	-Regional -Global	-Species survival probability	-Marine Sanctuary managers -Resource manager	-In Development
Effectiveness of habitat restoration	-Living Resource Impact - Essential Fish Habitat	-Seasonal -Yearly -Scenario	-Local -Regional	-Metric measuring restoration effectiveness	-Resource managers -State managers -Federal managers	-In Development -In Transition
Effectiveness of hydropower system modifications for survival of migrating fish	-Living Resource Impact -Endangered Species Act	-Scenario -Yearly	-Local	- Probability of individual fish survival -Probability of species recovery	-Local managers -State managers	-In Operation In Development
Projections of extinction risk for protected species	-Living Resource Impact -Endangered Species Act	-Scenario -Yearly	-Local -Regional	-Probability of species recovery	-Resource managers	-In Operation -In Development
Forecasts of the coastal ecosystem effects associated with upstream water management alternatives	-Living Resource Impact	-Daily -Seasonal -Yearly -Scenario	-Regional	-Metrics for impacts to the ecosystem under study	-City planners -Local managers -State managers -Federal managers	-In Development
Beach closure forecasting	-Human health impacts	-Near real time -Daily	-Local -Regional	-Probability of exceeding health standards	-Local managers -State managers	-In Development
Impact of climate change on coastal ecosystems	-Human health impacts -Living resource impact	-Months -Decades -Scenario	-Local -Regional	-Habitat inundation maps -Metrics for impacts to the ecosystem under study	-City and State planners -Local, State, Federal managers	-In Development
Forecasts of physical dynamics and their impacts on the ecosystem	-Living Resource Impact -Human health impact	-Near real time -Daily -Seasonal -Scenario	-Regional	-Forecast maps and time-series of key physical parameters -Metrics for impacts to the	-Resource managers -Federal managers -State managers	-In Development -In Transition -In Operation

				ecosystem under study		
New non-native species introductions	-Living Resource Impact	-Scenario	-Local -Regional	-probability of species invasion	-State managers -Federal managers	-In Development
Drinking water quality and quantity	-Human health impact	-Scenario	-Local -Regional	-Probability of exceeding health standards	-Local managers -State managers	-In Development
Onset, extent and impact to living resources of hypoxia in coastal areas	-Living Resource Impact	-Near real time -Seasonal -Scenario	-Local -Regional	-spatial and temporal maps of hypoxia -metrics for impacts to living resources	-State managers -Federal managers	-In Development
Water quality forecasts	-Living Resource Impact -Human health impact	-Near real time -Daily -Seasonal -Scenario	-Local -Regional	-spatial and temporal maps of key water quality variables	-State managers -Federal managers	-In Development -In Transition -In Operation
Ice thickness/extent and ecological impacts	-Living Resource Impact	-Scenario	-Local -Regional	-Metrics for impacts to the ecosystem under study	-Resource managers	-In Development
Water quantity impact on living resources	-Living Resource Impact	-Daily -Seasonal -Scenario	-Local -Regional	-Metrics for impacts to the ecosystem under study	-State managers -Federal managers -Resource managers	-In Development
Forecast of shellfish toxicity	-Living Resource Impact -Human health impact	-Near real time -Daily	-Local	-toxin accumulation in shellfish	-State managers -Resource managers	-In Development

Ecosystem White Paper #6

Science Requirements to Identify and Balance Societal Objectives

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> "Once we accept the concept of multispecies management, we are faced with the question, what (and how) do we optimize? We cannot answer this entirely in ecological terms but must introduce social and economic values …" (National Research Council 1980).

I. Description of the Issue

The question addressed by this paper navigates the murky waters where science intermingles with governance and all its cultural, political, economic, ethical, psychological, social and other human dimensions. The question is this: What should be the end(s) of coastal and ocean management? The National Oceanic and Atmospheric Administration (NOAA) provides an answer in the context of its strategic Ecosystem Mission Goal. This goal prescribes the protection, restoration and management of coastal and ocean resources following an ecosystem approach to management (EAM) that, among other criteria, balances diverse [societal] objectives[6] (Department of Commerce, 2005). For NOAA's purposes, then, the proper aim of coastal and ocean management is not any particular societal objective(s), but some sort of balance among them.

In the United States, at least four general types of institutions affect the spatio-temporal pattern of and relationships among ocean and coastal resource uses. The system of government, agencies, and management bodies (such as the Regional Fishery Management Councils) comprise a democratic institution of decision-making. The body of laws and distribution of property rights among the government and people constitutes a legal institution with rules that define the entitlements and responsibilities of people in society with respect to resource uses. The economic institution, which is closely tied to the law (e.g., enforcement, security of title, and so on), regulates the economic value of coastal and ocean assets in situ or their commodity and service flows in market and, increasingly, "non-market" situations. Finally, social institutions characterized by

[6] In full, NOAA defines an ecosystem approach as "management that is adaptive, specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple influences, and strives to balance diverse social objectives" (Department of Commerce 2005). We substitute *societal* for *social* objectives to refer to the variety of objectives endorsed by NOAA's constituents that are or may be affected by the condition and management of coastal and ocean ecosystems. This set of objectives includes both social and environmental objectives.

leisure, cultural, livelihood and other sociocultural dimensions mediate human influence on environmental systems and their management.

Whether democratic, economic, or (most likely) an interaction of institutions "balances" societal objectives, NOAA's vision of an EAM leaves open the following questions:

A. Who will identify and articulate the societal objectives that serve as the goals of coastal and ocean resource management decisions – and how?
B. What is meant by "balance" among societal objectives?
C. How do these institutions need to change to accommodate EAM and fulfill NOAA's Mission "to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs."

We consider these questions below, focusing on their implications for the ecosystem science conducted and sponsored by NOAA to fulfill its ecosystem mission needs. In keeping with our expertise, we emphasize economic and democratic mechanisms.

II. Science Capabilities Necessary to Support Decision Making

A. Incorporating Societal Objectives into Decision Processes

From a decision standpoint, if policy makers and resource managers are to "balance diverse societal objectives," as NOAA's commitment to an ecosystem approach to management requires, then decision-relevant societal objectives must be identified (and operationalized in the form of indicators) for use by policy makers and resource managers. Decision-relevant societal objectives are those for which their achievability will or may potentially be influenced by the condition and management of coastal and ocean environments. The selection of societal objectives for consideration in policy and resource management decisions can have profound implications for individuals, coastal communities, resource user groups, and the general public.

An emphasis on the role of decision processes in balancing diverse societal objectives is enhanced by a focus on the development of decision institutions designed with the proper incentives and restrictions that influence people to behave consistent with the EAM. In particular, Hanna (1998) recommends that EAM institutions promote multiple objectives, cost-effectiveness, legitimacy, flexibility, and long time horizons (stewardship). These traits would require a suitable set of well-defined property rights that evolved from an open, deliberative process that people believe was legitimate. The property rights needs to be indefinite, transferable, and enforceable in order for the other elements to be voluntarily internalized. For example, secure, indefinite title promotes stewardship (contrast the aquaculturalist and the fisherman making a living in an open access or regulated open access property rights regime where the rule-of-capture prevails). Exchange promotes multiple uses and flexibility as well as value. Ownership results in cost-effective behavior because you are accountable for costs.

Societal Objectives

Societal objectives influenced by coastal policy and management decisions include environmental goals (such as biodiversity) as well as human activities (including extractive resource uses such as fishing and non-extractive experiences such as boating) and their sociocultural significance. The sociocultural significance of resource uses encompasses an exceptionally diverse plurality of values (market- and non-market) that humans derive from and attribute to environmental systems. Environmental values prescribe conditions for environmental systems or their components – e.g., resilience or biodiversity. Social values prescribe conditions for the economic, cultural, political, institutional and other systems that embody our social lives – e.g., economic growth or cultural vitality. And many values blur this distinction by prescribing conditions at the interface of environmental and social systems (e.g., environmental justice is the aim of securing clean air and water to provide healthy living and working conditions for all people). The point here is that societal objectives are not *social* objectives. They include environmental and social ends as well as outcomes that blur the distinction. And both kinds of ends can be operationalized in the form of measurable indicators of ecosystem condition and management effectiveness.

The natural capital and functions integral to environmental systems provide services – referred to as ecosystem services – that contribute to human well-being by promoting the achievement of environmental and social values. Such services can be categorized as supporting (e.g., nutrient cycling and soil formation), provisioning (e.g., timber and food), regulating (e.g., water purification and flood control), and cultural (e.g., spiritual opportunities and aesthetic experiences). These services contribute to human well-being by directly and indirectly providing for values essential to personal and social security, basic material needs, physical and psychological health, good social relations, and freedom of choice and action to achieve personal values and foster personal identity (Millennium Ecosystem Assessment, 2005). Ecosystem services contribute to the full dimensionality and depth of human psychological and social experience, e.g. by enabling values such as security from natural disasters, livelihood, nutrition, social equity, recreational pleasure, cultural vitality, and aesthetically moving experience.

Natural capital, ecosystem services, and resource product flows provide a strong *instrumental* reason for valuing the environment – i.e., while they may be valued in their own right, they are also valued as a means to an end, namely, human well-being. In contrast, some regard non-human nature – whether species, habitat types, or even systemic processes such as the carbon cycle – as having *non-instrumental* value. Something is said to have non-instrumental value (sometimes called "intrinsic" value) when it is attributed value independently of its usefulness as a means to any end. Both instrumental and non-instrumental justifications support consideration of environmental values as part of the ensemble of societal objectives that, as the NOAA Ecosystems Mission Goal emphasizes, must somehow be balanced by coastal and ocean resource managers.

Participatory Research and Sociocultural Monitoring

A purpose of the political-policy process in our democratic society is to adjudicate personal preferences to represent collective ends – a debate that is (ideally, more rather than less) informed by scientific information and other sources of knowledge, diverse cultural perspectives, and reason-based discussion about values (ethical argumentation). The output of this debate is a set of federal laws, executive orders, and judicial decisions that, to some extent, represent societal objectives. (Let us refer to the objectives specified in such authorities as "policy ends.") Such authorities are directed by Congress, the President, and the courts to be implemented by the Department of Commerce, NOAA, NOAA's component organizations, and other governmental agencies with resource management responsibilities. Accordingly, the policy ends expressed by NOAA's authorities are an important source of societal objectives to serve as the ends of coastal and ocean resource management.

It would be democratically and practically disadvantageous to derive resource management goals solely from policy ends. From a democratic standpoint, policy ends may not represent the full ensemble of values that stand to be affected by resource management decisions. Social groups (and, consequently, their values) can be marginalized from political-policy processes, risking the undemocratic outcome of failing to consider a subset of societal values in coastal and ocean management decisions. From a practical perspective, engaging participatory decision processes as a way of recognizing the values of a diverse constituency can improve the substance, perceived legitimacy, and effectiveness of decisions (Mascia, 2003; Sutinen and Kuperan, 1999). In addition, authorities often leave societal objectives undefined or articulate them at a high level of generality that requires quantitative and/or qualitative specification to be operational for decision making.

For these reasons, a participatory approach to elucidating decision-relevant societal objectives is widely advocated as essential to democratic and effective coastal and ocean management (e.g., Mascia, 2003). There is "widespread consensus that forging partnerships with people and creating more meaningful opportunities for public participation should be part of the ecosystem [approach to] management paradigm" (Daniels and Walker, 1995; Thomas 1995; and Walker and Daniels, 1996 in Endter-Wada et al., 1998). Such a consensus is demonstrated by the many environmental regulations that require some form of public participation in environmental decision making – e.g., on the federal level, the Administrative Procedures Act, National Environmental Policy Act, National Marine Sanctuaries Act, Magnuson-Stevens Fishery Conservation and Management Act, Coastal Zone Management Act (NOAA Coastal Services Center, 2004).

Also, social science research is essential to design democratic and effective decision approaches such as collaborative learning and co-management. A National Research Council publication, *Decision Making for the Environment*, lays out research priorities for the social and behavioral sciences to improve decision processes affecting environmental quality (Stern and Brewer, 2005). In addition, Endter-Wada et al. (1998)

provide a useful discussion of social research contributions to public involvement in planning and policy making, summarizing them as follows:

> "Some social scientists focus their research and analysis on broader processes of group and societal decision-making; i.e., the objects of their science are these processes. Their work generally analyzes the structure and dynamics of various public involvement processes, the conditions under which these processes work best, their suitability for addressing different types of problems, their effectiveness in facilitating public involvement, and their success in improving situations or attaining different outcomes. … Other social scientists have borrowed heavily from conflict negotiation and mediation experiences outside natural resources (e.g., labor disputes, divorce settlements) and applied these techniques to understanding and managing those conflicts …"

In addition to social science research focusing on decision processes, sociocultural assessment and monitoring is crucial to identify stakeholders and their objectives for consideration via those processes. Among many useful guidance documents, the *Socioeconomic Manual for Coral Reef Management* (Bunce, 2000) is widely used as a tool for managers to establish socioeconomic monitoring programs. In addition, the Environmental Protection Agency (2002) provides a guide to community assessment that focuses on identifying community attitudes and values.

Economics Perspectives on Decision-Making and Resource Use

In the *MIT Dictionary of Modern Economics*, economists define economics as "the study of the way in which mankind organizes itself to tackle the basic problem of scarcity. … All societies have more wants than resources …, so a system must be devised to allocate these resources between competing ends." This proper definition shows that economics is important to EAM for more than measuring the economic notion of value and impacts of regulations. In addition, the ways that "mankind organizes itself" are more numerous and varied than the familiar marketplace.

The political policy process described above is an important option for EAM which yields deliberate decisions about objectives and resource use agreed upon by stakeholders. However, we can not expect one approach to work well in all circumstances. In some cases the scientific uncertainty surrounding EAM could hamstring a deliberative process due to the (transaction) costs of information and other requirements of negotiation (Libecap 1989). This seems to be most likely to occur when EAM is being used to manage increasingly more resource attributes than stock-wide biomass and age-structure, such as their spatial distribution and dynamics, and the integration of all with scientific results from other line offices (e.g., spatial prediction models that include weather and currents).

In these cases, instead of designing regulations, NOAA should consider the option of partnering with stakeholders to design institutions with the particular set of entitlements, rules, and attenuations necessary to create the expectation that people will behave consistent with EAM as new scientific (and other) information becomes known, technologies change, and preferences of the American public change (see Hanna 1998). Rather than expand regulations or renegotiate co-management agreements with every new piece of information, shift in state variables, or change in external factors (e.g., water movements, trade, etc.), the government could transfer (through sale, lease, auction) part of its legal “bundle of sticks” – i.e., property rights – to interested parties and make them responsible for decisions. The objective here is to design decision institutions run by stakeholders whose behavioral incentives match NOAA’s ideals for EAM but can respond to information and uncertainty more effectively than a political institution or process.

Concepts of Economic Value and Measurement for EAM

It is helpful, where possible, to measure gains and losses when speaking of balances, even where the natural environment is concerned, partly because losses almost always accompany a choice. In these cases, we think of the components of the ecosystem as assets (e.g., fish stocks, heat capacity of ocean waters, potential energy of currents) and flows (e.g., primary preproduction and oxygen production). In addition, human use (e.g., harvest) can alter the levels (rates) of assets and flows while at the same time generating human values. Finally, non-extractive uses of the ocean (e.g., whale watching, snorkeling on reefs) and even “non-uses” are valued by humans.

A variety of economic methods has been developed since the 1960s to measure the economic benefits (economic values) and costs (opportunity costs, or lost economic values) of environmental and natural resources (including quality dimensions, not discussed here) (see Freeman 1993). Besides market values such as commercial fishing, shipping, and oil and gas production which are analyzed by traditional methods, the so-called non-market values are classified and handled somewhat differently. Use values involve an in situ experience with (sport fishing) or without (sunbathing and swimming) extraction. Non-use values, which do not involve personal use, are divided into preservation or existence values and bequest values for future generations. Other value categories relate to uncertainty, including option value (an insurance coverage) and quasi option value for specific circumstances when irreversible development would most likely preclude learning about the suspected high value of a resource.

The various methods now available to assess the economic value of market-related natural resource assets (“related” because only what is extracted is valued in the National Income and Product Accounts) and non-market environmental and natural resource values - referred to collectively as environmental accounting - were recently endorsed by the NRC (1999). They include RUM models of recreational fishing, stated-preference research of the public’s valuation of marine reserves, and the asset value and resource rent associated with the rebuilt fish stocks, all done by NOAA staff. Current practices of measuring only the value of market activity associated with commercial fishing or recreational fishing give to stakeholders and fair to the American public a biased picture of the economic value of the resources and uses of the ocean under NOAA's authority. This will be a fertile and rewarding area of EAM research and policy for NOAA.

Recommendation 1: NOAA requires greater investment and intra- and interagency coordination in human dimensions research to identify societal objectives and incorporate them into coastal and ocean decision-making. Such research should focus on social science and humanities approaches to (a) improving and facilitating participatory decision processes, (b) social assessment and monitoring**,** (c) design and influence of governance arrangements on objectives and outcomes for society, and (d) describe and where possible quantify the values of natural resource assets and flows.

B. Balancing Societal Objectives

Tradeoffs among conflicting societal objectives, including conflicts between short and long term priorities as well as between environmental and social values, are fundamental to resource management (Hanna, 1998**;** Larkin, 1996; Link, 2002). Juda (1999) captures their centrality nicely:

> "All *societies are faced with mutually exclusive choices regarding the use of resources. In line with the opportunity of opportunity costs, the use of a limited resource obviates its alternative uses. Accordingly, some values must be given a higher, and others a lower, priority*."

Importantly, "tradeoff" does not mean "trade-in." That is, the de-prioritized value does not necessarily get discarded. In economics, tradeoffs imply comparing differences in small – i.e., marginal – changes of two or more activities to see if they are ever equal at some point. That point identifies where the combination of values is greatest.

NOAA's authorities offer little if any guidance regarding how to prioritize conflicting objectives or weigh benefits for current generations against opportunities for future generations. For example, National Standard 8 of the Sustainable Fisheries Act of 1996 redefines the goal of "maximum sustainable yield" as articulated in the Magnuson-Stevens Fishery and Conservation Management Act, requiring management plans to include measures minimizing adverse economic impacts to fishing communities. The standard leaves open the question whether the conservation and restoration of stocks is to receive priority over community objectives or vice versa. As Cicin-Sain and Knecht (2000) recognize, "if a stock is in grave danger of being depleted, fishing effort must be either greatly reduced, which is detrimental to dependent fishing communities, or allowed to continue, which is detrimental to fish stocks." In such instances, fisheries managers face a trade-off between the cultural and short run economic vitality of fishing communities and the preservation of stocks for future generations.

In more general terms, current and emerging management issues involve tradeoffs among the various benefits of agricultural production and water quality in the Gulf of Mexico and other areas (NCTC, 2000); off-shore energy development and resulting habitat damage, emissions, and oil spill risk; ship ballasting procedures and the introduction of invasive species; cultural, recreational, and other uses of coral reefs and their protection; the protection of marine mammals and human activities such as fishing and ship traffic; and aquaculture, which may spread disease among fish populations and poses a risk of non-native species introductions (U.S. Commission on Ocean Policy, 2004).

In view of the centrality of such trade-offs to coastal and ocean management, an EAM is an enterprise in constructing an acceptable vision rather than achieving an ideal world. That is, policy makers and managers are not in the business of maximizing everything at stake. They are in the business of compromising or sacrificing the achievement of some societal objectives in order to secure the possibility of others. Such decisions establish priorities that are both ethically weighty and socially controversial.

Beyond identifying societal objectives and facilitating their incorporation into decision making (discussed in the previous section), the aim of “striving to balance diverse [societal] objectives” prescribed by NOAA’s commitment to an EAM requires the following steps:

1. Identifying tradeoffs among societal objectives that enter into policy making and implementation, and management decisions;
2. Establishing priorities that are ethically defensible through means that are democratic or revealed by self-governance arrangements that are designed to create behavior that complies with EAM principle; and
3. Envisioning, implementing, and evaluating regulatory, participatory, technological, educational, institutional, and other strategies to achieve an acceptable integration of priorities.

Providing scientific information and tools essential to achieve the “balance” requirement of an EAM, then, requires providing scientific information and tools essential to support these steps and alternatives.

In the most general terms, an ecosystemic research approach and institutional structure is vital. This may seem obvious, yet (with laudable exceptions) most research supported and conducted by NOAA has an environmental science focus, i.e. on observation and forecasting of biological, physical, and chemical systems. A truly ecosystemic focus would integrate research themes such as human causes and consequences of environmental stress (see Stern et al., 1992), decision approaches (see Brewer and Stern, 2005), and governance arrangements – especially for LME's (e.g., Juda, 1999). In terms of "business strategy" or institutional structure, such a commitment requires cross-disciplinary integration in addition to intra- and inter-Goal Team coordination and social science representation at senior levels. The need for a truly ecosystemic focus – in terms of research content, institutional organization, and staffing and senior representation – is supported and elaborated by a Social Science Review Panel report to the NOAA Science Advisory Board (2003).

EAM will complicate NOAA’s missions in scientific research and management for several reasons. First, by its nature, EAM will expand the number and type of resources and resource attributes being researched and managed from the unit-stock biomass and age-structure of target species to interactions (such as predation) and the spatial heterogeneities and topologies (i.e., relationships, such as connectivity) of resources, other species (including humans), and habitat. This places a heavy demand on information which, at the moment, is missing or highly uncertain (e.g., weather → primary production/currents → survival of fish larvae → recruitment → fishermen's behaviors → management response → sociocultural and economic impacts followed by mitigation measures and adaptive responses that feedback to influence biophysical systems). Second, EAM will force NOAA to find legal, ethical, and cost-effective ways to inform and facilitate the identification and evaluation of tradeoffs between resource uses and between resource users. And third, EAM should make it self-evident that management is inherently a normative endeavor (Lackey 2005). That is, we manipulate the environment in order to satisfy human values which locate value in the human experience (anthropocentric), ecological systems (ecocentric) and/or living entities such as species (biocentric). Even policies that preserve a species or set up a network of marine reserves are normative (i.e., they aim to restore nature to a desired previous state).

More specifically, identifying tradeoffs (1) requires a picture of the viability of societal objectives, individually and in relation to one another, as they are likely to be influenced by interactions within and between human and environmental systems. The challenge of evaluating tradeoffs can be illustrated by applying portfolio theory to fisheries. Assume that the overall objective for an LME (or suitable sub-region) is to balance expected aggregate returns (i.e., aggregate income from all species plus changes in asset values) against the return risks associated with recruitment, various interactions (e.g., predation, multi-species harvest technology, product substitution in markets), and other uncertainties (Edwards, Link, and Rountree, 2004). Internalizing interactions into multi-species management requires deliberate tradeoffs between yields of different species. Since yields support a plurality of economic, cultural, spiritual, and recreational values, tradeoffs among yields give rise to tradeoffs among such values. For example, increasing the yields of highly valued piscivorous species might require fisheries for their prey to be cut way back. Or, as Gulland (1982) recommended for the North Sea, fish down the top piscivores, such as cod, and fish the herbivores only moderately in order to encourage the growth of flounders and other valuable benthivores.

Although this example is confined to multi-species management, the portfolio framework is a considerable step in the direction of EAM because it deals directly with interactions and uncertainty in a search for what an ecosystem can produce of economic value. Furthermore, it can be applied to more difficult resource scenarios, such as tradeoffs between fisheries and other human endeavors such as marine reserves, aquaculture parks, and oil and natural gas leases. However, like the single-species approach which is described primarily in terms of the natural sciences, the portfolio framework is a two-legged chair that needs to be implemented with a management approach that involves people and behavior, both in government and at sea. Thus, once again, we meet the choice of which type of institution will properly define the objectives of a technical framework such as the portfolio framework - (1) one that increases the number of regulations to a large extent (2) one that negotiates solutions to the many interactions democratically; or (3) one that entrusts the design of EAM institutions to have the correct incentive structures to influence socially-appropriate behavior? This is a question of governance and resource allocation under uncertainty.

The power of the EAM concept as an instrument to envision and sustain a better world derives from its broad applicability to decision making across sectors, incorporating non-market values, and utilizing alternatives to command-and-control regulation, such as democratic and economic alternatives, to elucidate values and adjudicate conflict among them. The social sciences (economic and non-economic) and humanities offer diverse approaches to establishing priorities in this broader context, including cost-benefit analysis; tradeoff analysis, which can be utilized in a participatory decision process (e.g., Brown, 2001), conflict mediation (e.g., McCreary et al.), discursive ethics (e.g., O'Hara, 1995) , and contracting (Townsend and Pooley 1995).

Once priorities are established, what science is required to inform decision-makers envisioning and implementing strategies to achieve and sustain them (3)? To provide one example, Sutinen et al. (2000) lay out socioeconomic research needs in a "Framework for Monitoring and Assessing Socioeconomics and Governance of Large Marine Ecosystems."

1. Identify principle uses of LME resources;
2. Identify LME resource users and their activities;
3. Identify governance mechanisms influencing LME use;
4. Assess the level of LME-related activities;
5. Assess interactions between LME-related activities and LME resources;
6. Assess impacts of LME activities on other users;
7. Assess the interactions between governance mechanisms and resource use;
8. Assess the socioeconomic importance of LME-related activities and economic and sociocultural value of key uses and LME resources;
9. Identify the public's priorities and willingness to make tradeoffs to protect and restore key natural resources;
10. Assess the cost of options to protect or restore key resources;
11. Compare the benefits with the costs of protection and restoration options; and
12. Identify financing alternatives for the preferred options for protecting/restoring key LME resources.

One research need omitted by this framework is an analysis of social factors driving human activities that significantly contribute to ecosystem stress – e.g., demographic change; attitudes, values and beliefs; technological innovation; political forces; or regulatory instruments. Knowledge of social drivers is essential to focus environmental protection, restoration, and management strategies on underlying causes of stress.

Finally, research is necessary to identify and facilitate governance patterns conducive to priority setting and strategy development in the context of LME policy and management. Governance refers to the "formal and informal arrangements, institutions, and mores which determine how resources or an environment are utilized; how problems and opportunities are evaluated and analyzed; what behavior is deemed acceptable or forbidden; and what rules and sanctions are applied to affect the pattern of resource and environmental use" (Juda, 1999). Juda (1999) lays out considerations for developing and implementing a governance approach. Townsend and Pooley (1995) provide a broad taxonomy of "distributed governance" (i.e., how rights and responsibilities are distributed across government, the fishing industry, and fishing communities) and contrast the current regulatory approach with external institutional relationships (co-management, harvest rights, and contracting) and internal relationships (self-organizing groups, cooperative management, communal management, corporate management). Notice that the federal government is party to each form of external governance. Further, different combinations of external and internal governance arrangements will result in a different balance of societal objectives and different set of outcomes for the environment and interested parties. For example, objectives from a regulatory arrangement will differ from those associated with the combination of co-management/corporate management and from contracting/self-organizing groups.

Recommendation 2: NOAA requires greater investment and intra- and interagency coordination in social science and humanities research on topics, such as those discussed above, that support NOAA's aim of "striving to balance diverse [societal] objectives." This is an enterprise in identifying tradeoffs; establishing priorities that are ethically defensible to stakeholders and fair to the American public through various means such as democratic and/or other combinations of distributed governance that match EAM principles and provide self-governance incentives; and developing and implementing strategies informed by ecosystem science incorporating human dimensions.

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APPENDIX 4 INTEGRATED ASSESSMENTS

These are illustrations of the work being done now to place assessments of specific ecosystem features into greater ecosystem contents. Although these fall far short of the integrated ecosystem assessments envisioned by the eETT (see the text box in section IV-F), they illustrate that process of moving assessments to a greater ecosystem scope are already underway in NOAA.

Gulf of Mexico

An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico
This assessment summarizes the state of knowledge of the extent, characteristics, causes, and effects of hypoxia in the northern Gulf of Mexico. It outlines a range of approaches for reducing those effects and examines the costs and benefits associated with those approaches. It also describes additional research and monitoring needed to reduce uncertainties, to track progress following any mitigation efforts, and to identify potential future adjustments to any initial actions that may be taken to reduce hypoxia and improve water quality. Source -- http://www.nos.noaa.gov/products/pubs_hypox.html#fia

National Coastal Condition Report II (2005): Chapter 9 – Health of Galveston Bay for Human Use
This final chapter of the NCCR assesses the health of an estuary based on its ability to meet society's desired uses. Using Galveston Bay (the largest estuary on the Texas coast) as an example, this chapter examines the following questions: 1) What are society's stated uses for this system; 2) How well are those uses being met; 3) In instances in which a particular use is not being achieved to the desired level, are there relationships between the impairment and the NCCR indicators? If so, how might improving one or more of the indicators affect a particular use? Addressing estuarine health in this manner can help researchers interpret existing data in terms of an estuary's ability to meet society's desired uses, as well as drive the collection of new data directly related to perceived problems. Source -- http://www.epa.gov/owowwtr1/oceans/nccr/2005/Chapter9_GalvestonBay.pdf

Southeast

An Integrated Assessment of the Introduction of Lionfish (Pterois volitans/miles complex) to the Western Atlantic Ocean
This assessment summarizes what is known about the introduction of lionfish, to identify the potential effects on marine ecosystems, to discuss management and policies related to the introduction of lionfish, and more generally, to address the threat of marine fish invasive species. Source -- http://coastalscience.noaa.gov/documents/lionfish_ia.pdf

National

An Assessment of Coastal Hypoxia and Eutrophication in U.S. Waters

The assessment examines the ecological and economic consequences of hypoxia in United States coastal waters; alternatives for reducing, mitigating, and controlling hypoxia; and the social and economic costs and benefits of such alternatives. Source -- http://coastalscience.noaa.gov/documents/coastalhypoxia.pdf

The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002

In response to growing concerns about the condition of reefs, the United States Coral Reef Task Force (USCRTF) called for a nationally-coordinated mapping and monitoring program to help track and evaluate the condition of U.S. coral reefs and report to the Nation every two years. This report is the first effort to collect consistent, comparable scientific information to assess the status of coral reef health. This report assesses the condition of reef resources, ranks the relative importance of environmental pressures that have degraded reefs, highlights significant actions taken by USCRTF agencies to conserve coral reef ecosystems, and provides recommendations from coral reef managers to fill information gaps. It forms a baseline against which future assessments will be compared, allowing scientists to track and ultimately predict changes in reef conditions. Source -- http://coastalscience.noaa.gov/documents/status_coralreef.pdf

The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005

The purpose of this report is to provide an assessment of the current condition of coral reef ecosystems in U.S. jurisdictions. The report focuses primarily on shallow-water portions of these states and territories, from the shoreline to the maximum depth at which sunlight dependent corals can survive. Information is provided on the geographic distribution of reefs; the understanding of the 13 key natural and anthropogenic threats; existing monitoring programs, methodologies, and data; current management actions; and summary of the status each jurisdiction's coral reef ecosystems. Source -- http://ccma.nos.noaa.gov/ecosystems/coralreef/coral_report_2005/

National Assessment of Harmful Algal Blooms in US Waters

The assessment presents a synthesis of current research and management expertise on the causes, consequences, and current status of harmful algal blooms (HABs) nationwide and presents alternatives and recommendations for addressing HABs and their impacts. This assessment was developed by the Task Force on Harmful Bloom and Hypoxia under the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR). It was a multi-agency, multi-disciplinary effort that included input from States, Indian tribes, industry, nonprofit organizations, and other stakeholders. Source -- http://www.cop.noaa.gov/pubs/habhrca/Nat_Assess_HABs.pdf

Our Living Oceans :

Periodically, NMFS releases a comprehensive assessment of the status of fishery populations and protected species assessed by the Agency. This report provides a comprehensive assessment of the status of biological populations, in relation to a number of human factors such as fishing, habitat change and ocean variability that influenced biological resources http://www.st.nmfs.gov/st2/pdf.htm

Regional Efforts

Alaska

One of the most comprehensive annual assessments of ecosystem status is compiled in support of the North Pacific Fishery Management Council's Groundfish Management Plans. This "Ecosystem Considerations Chapter" provides comprehensive sets of time series of physical oceanography, habitat and biological variables, along with interpretations of changes and implications for biological productivity. It is produced annually by NMFS, Alaska Fisheries Science Center, OAR, Pacific Marine Environmental Laboratory, and a number of other institutional and academic partners: http://www.afsc.noaa.gov/refm/docs/2005/EcoChpt.pdf

West Coast

In the West Coast, the Pacific Ocean observing System (PaCOOS), provides integration of physical and biological data sets. PaCOOS is concentrating on making historical data sets available in web compatible ways, eventually leading to more integrated assessment capabilities:
http://www.pacoos.org/

Northeast

In the Northeast, the NMFS Northeast Fisheries Science Center has produced periodic assessments of a variety of ecosystem indicators, and is conducting research on the adequacy of indicators for determining the status of the NE shelf ecosystem :
http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0211/

APPENDIX 5 ECOSYSTEM APPROACHES TO MANAGEMENT

The incorporation of more general ecosystem principles into traditional management approaches for coastal and marine issues has progressed substantially in recent years. In particular, ecosystem approaches to fisheries management have progressed from the theoretical to the implementation stage. This has occurred because of the growing realization that fisheries management is imbedded in a larger set of ocean policy decision making involving living marine resources and attributes of their supporting ecosystems. Efforts to include ecosystem attributes in fisheries are occurring world-wide, and "best practices" are being shared among programs operating in the eastern and western Atlantic oceans, the north and western Pacific, in Antarctica, and elsewhere. General principles, goals, and objectives for the inclusion of ecosystem considerations in fisheries have been articulated at the international level (e.g., by the United Nations Food and Agriculture Organization [FAO], and other regional bodies including ICES, PICES and others). In the United States, numerous national and regional efforts have begun that have articulated the general approaches and are beginning to adapt them to particular fishery applications (See White Paper 2 in Appendix 3). Highlighted below are a few recent examples of the incorporation of ecosystem considerations in management.

Ecosystem Approaches at the International Level

The Food and Agriculture Organization of the UN has actively pursued the establishment of guidelines to implement ecosystem approaches to management as part of its oversight of regional fishery management organizations. These principles are consistent with those recommended above for the USA national level. As part of the United Nations Food and Agriculture Organization's (FAO) long-term planning for ecosystem approaches, they have provided various documents aimed at technical experts and a variety of lay audiences to encourage the concepts. Consistent with recommendations in our report, FAO notes that key research requirements for an ecosystem approach include: (1) conducting fishery and ecosystem impact assessments, (2) evaluating socio-economic considerations, (3) assessment of the efficacy of proposed management measures, (4) assessment and improvement of management measures, and (5) long-term monitoring including practical sets of indicators and reference points.
http://www.fao.org/fi/nems/news/detail_news.asp?lang=en&event_id=34029

Ecosystem Approaches at the National Level (USA)

Ecosystem Principles USA

The re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act in 1996 required NOAA to compile a report assessing the extent to which ecosystem principles have been used in fisheries management and how such principles can be further implement to improve management of living marine resources. The full report, published in 1999 emphasized the importance of compiling explicit ecosystem plans underpinning fishery management programs, and described six actions to implement such plans, including: (1) encouraging managers to apply ecosystem principles, goals, and policies, (2) providing training to managers and staff, (3) preparing guidelines for fishery ecosystem plans, (4) developing pilot programs, (5) providing oversight to ensure development and compliance, and (6) enacting legislation enabling fishery ecosystem plans. The ecosystem principles are described in detail in: http://www.st.nmfs.gov/st7/documents/epap_report.pdf

Regional Implementation USA

There is a growing body of regional applications of ecosystem principles in fisheries management in various parts of the United States. Some of these are occurring at the federal level, and many at the state or inter-state level. Below are a few examples of ecosystem principles being incorporated in domestic management.

Chesapeake Bay

States bordering the Chesapeake Bay have long noted the interrelationships among commercial species in the Chesapeake Bay, including oysters, blue crab, striped bass, menhaden, and other species. The world's largest estuary is home to a variety of life stages of these and numerous other species. Predator prey relationships among the species are critical characteristics of the ecosystem. Optimal management of the Bay's resources will increasingly depend on understanding the trophic dynamics among the managed species and other biota. As well, the bay watershed drains immense agricultural and urban areas. Nutrient pollution is a significant issue, and so ecosystem principles underpinning integrated management of the Bay's resources are critical components of balancing human and resource needs. NOAA's Chesapeake Bay office, using a broad scientific and stakeholder process developed a prototype fisheries ecosystem plan as a means to focus discussion of using current understanding of the Chesapeake Bay ecosystem http://noaa.chesapeakebay.net/docs/FEP_DRAFT.pdf.

Puget Sound Ecosystem Research Plan Initiative

The ecosystem of Puget Sound is home to a vast array of living resources, including indigenous runs of salmonids, marine mammal populations, including killer whales, and numerous other populations of finfishes, invertebrates, and mammals. Given the growing human population adjacent to the sound, and the land-based resource industries (agriculture and forestry), shoreline modification and other activities serious declines have been noted in conditions for sustaining the living resources of Puget Sound. Integrated assessment and management of the Sound's resources is seen as imperative. To address these needs, a number of state and federal agencies and local conservation organizations and municipalities have been developing ecosystem approaches to conservation planning in the Sound, e.g. the Shared Strategy for Salmon Recovery (http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Draft-Plans.cfm), Governor's Puget Sound Partnership http://www.psat.wa.gov and the Nearshore Strategy Initiative. These efforts will integrate endangered species recovery planning in the matrix of multiple use planning for the area. NOAA is contributing to these efforts in a variety of ways but most directly it is taking the lead through its Northwest Fishery Science Center to convene regional science and management agencies and groups develop a synthesis document for ecological and socio-economic information as a starting point for diagnosing problems and solution and developing an ecosystem research plan (http://www.nwfsc.noaa.gov). Academic institutions have developed other synthetic data sets on which and ecosystem approach can be built, e.g., PRISM(http://www.prism.washington.edu/regionalissues/category.jsp?keywords=REGNLS&category=Ecosystem%20Research%20and%20Management.

Western Pacific Fishery Management Council

The Western Pacific Council (responsible for the Hawaiian Islands and a variety of island archipelagos in the Pacific) is in the process of developing archipelagic fishery ecosystem plans that would eventually replace its separate Pacific-wide fishery management plans for coral reef fish, precious corals, bottomfish, seamount groundfish, and crustaceans. These plans outline how bottomfish, coral conservation, and socio-economic considerations can be integrated in a geographically explicit series of plans (e.g., for the Mariana Archipelago, the Hawaiian Island Archipelago, Samoa Islands and the Pacific Remote Islands). Large pelagics would continue to be managed on a Pacific-wide basis given the scale of their ecosystem migrations http://www.wpcouncil.org/.

Alaska Region

The North Pacific Fishery Management Council has been at the forefront of implementing ecosystem considerations into their fishery management plans (See Appendix 3 White Paper 2). In particular, the NPFMC has incorporated conservation of cold water coral habitats by implementing fishery closed areas explicitly to protect these fragile habitats. Other habitats of particular concern have been reserved from fishing activities, for various purposes including integrated management of protected species including sea lions and other mammals. Multiple ecosystem-based measures including reduction of bycatch, accounting for trophic relationships among species, and conservative long-term management approaches have been part of its ecosystem approach. The Council routinely summarized a wide variety of ecosystem data and indicators as part of its annual groundfish management planning. More recently, the Council, in concert with the State of Alaska and stakeholder groups, has been considering how to implement area-based ecosystem plans (e.g., for the Aleutians and other defined areas)
http://www.fakr.noaa.gov/npfmc/current_issues/ecosystem/Ecosystem.htm

Atlantic Seaboard and Gulf of Mexico

As part of the 2004 NOAA budget, Congress included $2 million to advance ecosystem approaches for the four fishery management councils in the Atlantic and Gulf. As part of this project each of four councils (New England, Middle Atlantic, South Atlantic, and Gulf of Mexico) were provided funding to survey and understand ecosystem issues relevant to their activities. These reports are being compiled by the various Councils now, and identify the particular issues in their respective areas requiring ecosystem approaches to management. Ongoing work in the Gulf of Mexico as part of this project is described in:

http://www.gulfcouncil.org/downloads/GMFMC%20Ecosystem%20Fisheries%20Management%20Report.pdf

These few examples cited above are not meant to be a comprehensive assessment of the state of implementation of ecosystem approaches to fisheries management either nationally or internationally. They do illustrate, however, as a sector, that fisheries has embraced the concepts inherent in ecosystem approaches and that fisheries managers are attempting to develop these concepts into workable regional implementations.

APPENDIX 6 REFERENCES

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